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Zircon U–Pb ages of the granitic rocks in the Chikuhi area, central Kyushu, southwest Japan

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Abstract Zircons U-Pb ages were obtained from 5 granitoid samples in central Kyushu, southwest Japan. Two samples from Kikuchi Granite indicate ages of 106.6 ± 0.9 and 105.7 ± 1.2 Ma. Two samples from Tamana Granodiorite indicate ages of 105.7 ± 0.7 and 105.5 ± 0.9 Ma. The sample from Tsutsugatake Granite indicates an age of 106.0 ± 1.0 Ma. Errors are with 95% confidence interval. Including a previously reported age, zircon U–Pb ages in the study area concentrate around 106 Ma. The zircon ages are thought to be the plutonic age of the granitoids. Although 121–117 Ma of whole rock Rb–Sr ages was previously thought to be the plutonic ages of granitoids in this area, this assumption needs to be recorrected.

Key words: plutonic age, granitoid, Early Cretaceous, central Kyushu

Introduction

Kyushu is tectonically subdivided to three parts, northern, central and southern Kyushu, by the Matsuyama-Imari and Usuki-Yatsushiro tectonic lines (Fig. 1). Basement rocks in northern and central Kyushu consist of Permo-Jurassic accretionary complexes with Cretaceous granitoids. Basements in central Kyushu expose only the southernmost and northern parts called the Higo belt and Chikuhi area, respectively, due to subsidence in the Beppu-Shimabara Graben and covering of volcaniclastics from Neogene to Quaternary volcanos.

Because whole rock (WR) Rb–Sr age was believed to close from crystallization to cooling in igneous rocks (e.g. Moorbath, 1975; Roddick and Compston, 1977), it was thought to be suitable for plutonic age of granitic rocks. Hence, the plutonic age of Cretaceous granitoid in northern and central Kyushu had been discussed using WR Rb–Sr ages in spite of their large uncertainties. These days, zircon U–Pb method which has much higher precision, accuracy and closure temperature than WR Rb–Sr method has become common and it is thought to more accurately indicate plutonic age of granitoids.

In northern Kyushu, the plutonic ages of granitoids had been thought to be 118-88 Ma based on WR Rb–Sr age (118 ± 11 Ma to 88 ± 18 Ma; 2σ; Osanai *et al.*, 1993; Owada *et al.*, 1999). The ages of granitoids have since been updated as 107-98 Ma by zircon U–Pb age (107.4 ± 0.8 Ma to 97.9 ± 1.4 Ma, 95% conf.; Adachi *et al.*, 2012; Miyazaki *et al.*, 2018; Yuhara *et al.*, 2019).

In the Chikuhi area, only one zircon U–Pb age has been reported (Miyazaki *et al.*, 2018). In this paper, five new zircon U-Pb ages of granitoids are obtained. The main purpose of this work is improvement of the age data of granitic rocks in central Kyushu. The result will contribute to clarify the role of Kyushu in the tectonic framework of Japanese Islands.

Geological setting

Cretaceous granitic rocks in the Chikuhi area (Fig. 2) are divided into “older” and “younger” types (Owada *et al.*, 1999; Kamei *et al.*, 2002). The older type granitoids mostly comprise granodiorite to tonalite containing hornblende, whereas the younger type granitoids comprise peraluminous granodiorite to granite containing white mica and sometimes including garnet.

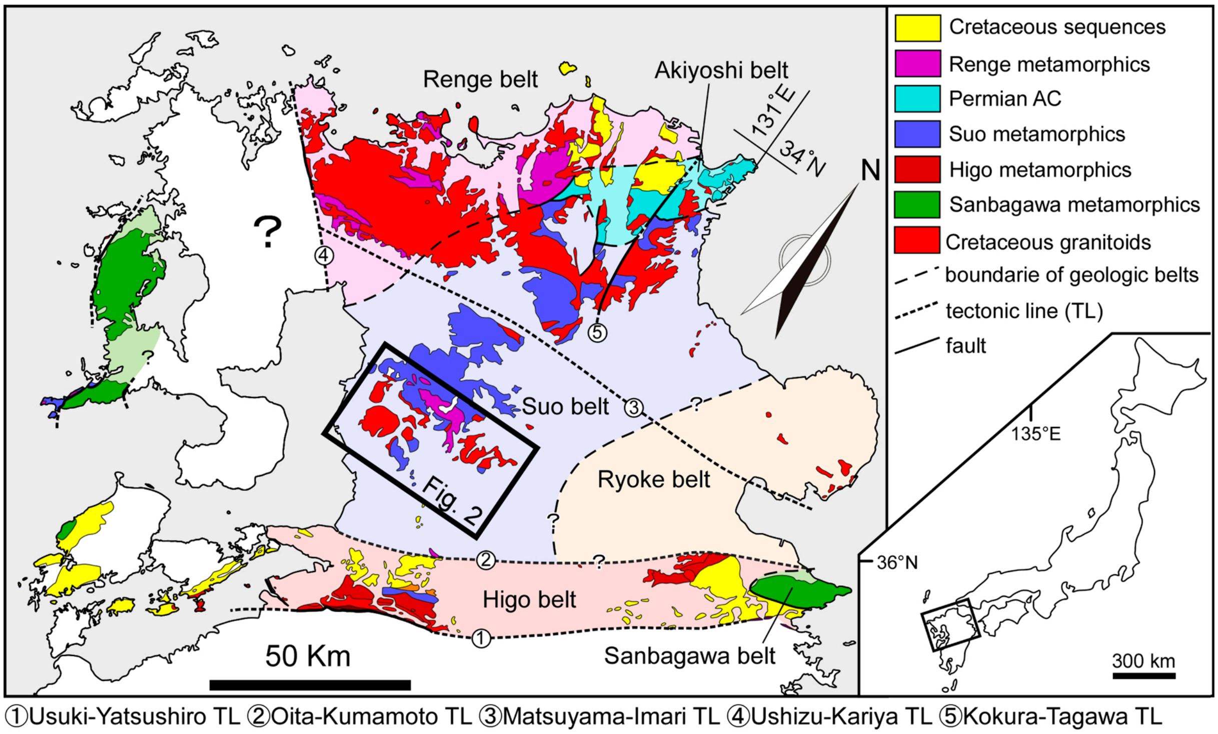

Fig. 1. Distribution map of the pre-Paleogene rocks in northern Kyushu.

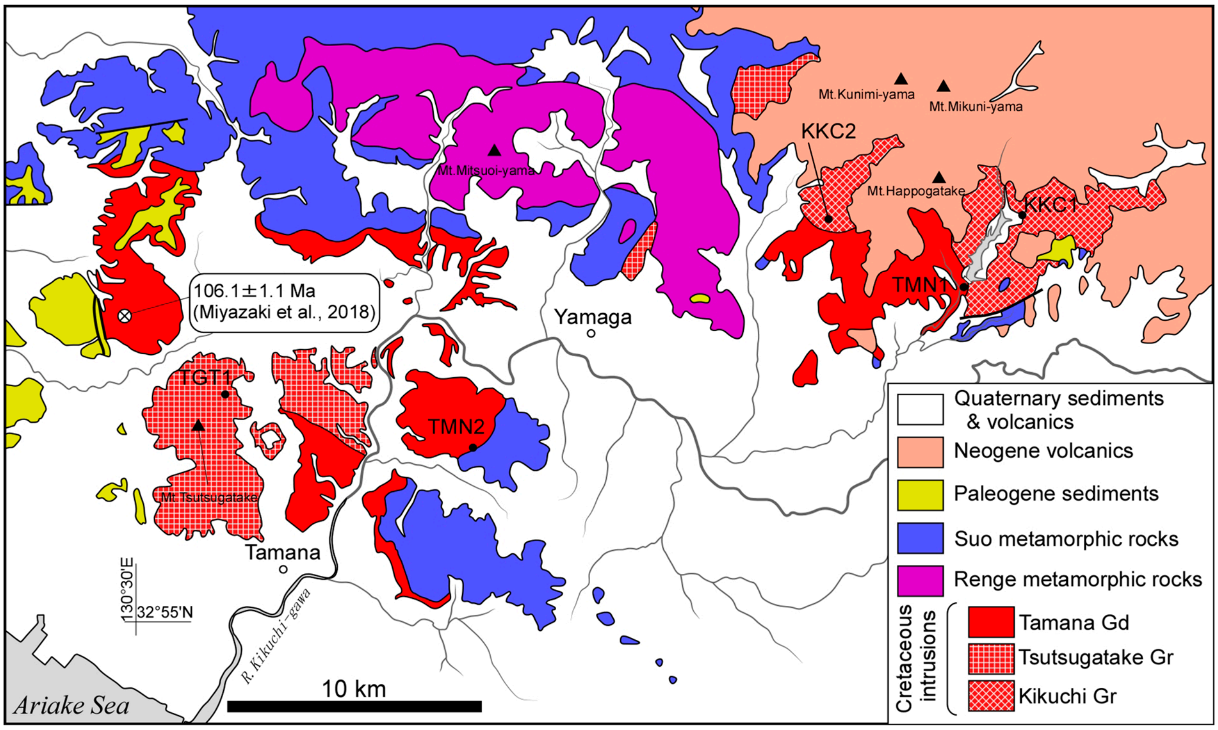

Fig. 2. Geological map of the study area showing the sampling localities, modified after Hoshizumi *et al.* (2004). Gd: granodiorite, Gr. Granite.

Granitoids in the Chikuhi area are divided into three bodies (e.g. Kamei *et al.*, 2009; Kamei and Osanai, 2010); Tamana granodiorite which is the older type, and Kikuchi and Tsutsugatake granites which are the younger type. The Tamana granodiorite is course to medium grained hornblende-biotite granodiorite. Biotite and hornblende K–Ar ages in the granodiorite are 99.7±2.5 Ma and 106.0±2.6 Ma, respectively (Tomita *et al.*, 2008). Recently, the zircon U–Pb age of 106.1±1.1 Ma (95% conf.;

Miyazaki *et al.*, 2018) was reported. The Kikuchi granite comprises fine to medium grained biotite granite to granodiorite sometimes containing white mica and/or garnet. The WR Rb–Sr isochron age is 121.3 ± 8.4 Ma (2σ; Osanai *et al.*, 1993), whereas the K–Ar age of muscovite is 95.3 ± 4.8 Ma (Sasada, 1987). Tsutsugatake granite is fine to medium grained two mica-garnet granite. The WR Rb–Sr isochron age is 116.8 ± 12.7 Ma (2σ; Osanai *et al.*, 1993), whereas biotite and muscovite K–Ar ages are 95.0 ± 4.8 Ma and 95.1 ± 4.8 Ma, respectively (Sasada, 1987). According to classical interpretation based on closure temperatures of minerals used for dating, granitoids in this area were thought to be formed at 121-117 Ma, and had been cooled until ~95 Ma (Kamei and Osanai, 2010).

Analytical methods

At first, the rock samples were scrubbed, and washed in an ultrasonic bath for ten minutes to avoid surface zircon contaminants. Fragmentation of the rock sample was conducted by a high voltage pulse power selective fragmentation equipment, SELFRAG Lab (Selfrag AG). The zircon grains were handpicked from heavy fractions that were separated through heavy-liquid techniques. Zircon grains from the samples, the zircon standards TEMORA2 (416.78 Ma; Black *et al.*, 2004) and OD-3 (33 Ma; Iwano *et al.*, 2013), and the glass standard NIST SRM610 were mounted in an epoxy resin and polished till the surface was flattened with the center of the embedded grains exposed. Before the mounting and polishing, secondary electron (SE) images of each grain were taken for morphological note. After the mounting and polishing, backscattered electron (BE) and cathodoluminescence (CL) images of zircon grains were taken. Scanning electron microscope-cathodoluminescence equipment, JSM-6610 (JEOL) and a CL detector (SANYU electron), were used for SE, BE and CL images. The images were used to select the sites for analysis. U–Pb dating of the samples was carried out using laser ablation inductively coupled plasma mass spectrometry using an NWR213 (Elemental Scientific Lasers) and Agilent 7700x (Agilent Technologies). All processes for sample preparation and analysis were conducted at the National Museum of Nature and Science, Tsukuba, Japan. The experimental conditions and the analytical procedures used for measurements followed Tsutsumi *et al.* (2012), with the additional devices of a buffered type stabilizer (Tunheng and Hirata, 2004) and TwoVol2 sample cell also applied. The spot size of the laser was 25 μm. A correction for common Pb was made on the basis of the measured $^{207}Pb/^{206}Pb$ ratio (^{207}Pb correction), $^{208}Pb/^{206}Pb$ and Th/U ratios (^{208}Pb correction) (e.g. Williams, 1998) and the model for common Pb compositions proposed by Stacey and Kramers (1975). In this paper, we adopt ^{207}Pb correction for age discussion because it is effective for calculating Phanerozoic $^{238}U–^{206}Pb^*$ age compared to ^{208}Pb correction (e.g. Williams, 1998). ^{208}Pb corrected $^{238}U/^{206}Pb^*$ and $^{207}Pb^*/^{206}Pb^*$ ratios are used for concordia plots. Pb* indicates radiometric Pb. The pooled ages presented in this study were calculated using Isoplot/Ex software (Ludwig, 2012). The data of secondary standard OD-3 zircon obtained during analysis yielded weighted mean ages of 32.3 ± 1.1 Ma (n = 8; MSWD = 0.35; when KKC1, KKC2 and TMN1 were analyzed) and 31.7 ± 1.4 Ma (n = 5; MSWD = 1.13; when TMN2 and TGT were analyzed). MSWD is acronym of mean square weighted deviation, which is calculated from square root of χ^2 value.

Sample descriptions and age results of zircon

Table 1 lists zircon data in terms of the fraction of common ^{206}Pb, U, and Th concentrations, Th/U, $^{238}U/^{206}Pb^*$ and $^{207}Pb^*/^{206}Pb^*$ ratios, and radiometric $^{238}U/^{206}Pb^*$ ages of the samples. All errors are 1σ level. All zircons in the samples show rhythmic oscillatory and/or sector zoning in CL images (Fig. 3), which is commonly observed in igneous zircons (e.g. Corfu *et al.*, 2003). Errors of weighted mean zircon U-Pb ages are at 95% confidence interval (95% conf.). Concordia and age distribution diagrams are shown in Fig. 4 and 5, respectively. The obtained weighted mean ages and sample localities are summarized in Table 2.

All rock samples are stored in the National Museum of Nature and Science. The registration number of each sample can be found from the rock specimen number in the collection database of the

Table 1. LA-ICP-MS U–Pb data and calculated ages of zircons in the samples.

Labels	$^{206}Pb_c$ (1) (%)	U (ppm)	Th (ppm)	Th/U	$^{238}U/^{206}Pb^*$ (1)	$^{207}Pb^*/^{206}Pb^*$ (1)	$^{238}U/^{206}Pb^*$ age (1) (Ma)	$^{238}U/^{206}Pb^*$ age (2) (Ma)	Remarks
Kikuchi granite (KKC1)									
KKC1_01.1	0.00	366	205	0.57	58.56 ± 1.34	0.0460 ± 0.0035	109.2 ± 2.5	109.2 ± 2.5	
KKC1_02.1	0.00	368	155	0.43	59.14 ± 1.49	0.0410 ± 0.0036	108.1 ± 2.7	108.1 ± 2.7	
KKC1_03.1	0.44	816	241	0.30	59.52 ± 1.09	0.0441 ± 0.0033	107.4 ± 2.0	107.9 ± 1.9	
KKC1_04.1	0.00	123	47	0.39	57.43 ± 2.32	0.0375 ± 0.0056	111.3 ± 4.5	111.3 ± 4.5	
KKC1_04.2	0.35	1004	596	0.61	57.44 ± 0.98	0.0418 ± 0.0037	111.3 ± 1.9	111.7 ± 1.8	
KKC1_05.1	0.58	418	232	0.57	60.52 ± 1.41	0.0477 ± 0.0067	105.7 ± 2.4	105.7 ± 2.4	
KKC1_06.1	0.00	147	75	0.53	58.53 ± 2.01	0.0407 ± 0.0058	109.2 ± 3.7	109.2 ± 3.7	
KKC1_07.1	0.37	452	215	0.49	56.70 ± 1.25	0.0484 ± 0.0054	112.7 ± 2.5	112.7 ± 2.4	
KKC1_08.1	0.00	356	240	0.69	57.03 ± 1.31	0.0505 ± 0.0032	112.0 ± 2.5	111.7 ± 2.6	
KKC1_09.1	1.00	356	216	0.62	60.94 ± 1.49	0.0425 ± 0.0072	104.9 ± 2.5	105.7 ± 2.5	
KKC1_10.1	0.00	805	632	0.81	58.48 ± 1.05	0.0483 ± 0.0026	109.3 ± 2.0	109.3 ± 2.0	
KKC1_11.1	0.00	1237	421	0.35	57.53 ± 0.95	0.0494 ± 0.0019	111.1 ± 1.8	110.9 ± 1.8	
KKC1_12.1	0.00	874	504	0.59	58.79 ± 0.97	0.0443 ± 0.0021	108.7 ± 1.8	108.7 ± 1.8	
KKC1_13.1	0.00	435	261	0.62	60.59 ± 1.43	0.0470 ± 0.0033	105.5 ± 2.5	105.5 ± 2.5	
KKC1_13.2	0.00	1418	465	0.34	60.59 ± 0.92	0.0484 ± 0.0018	105.5 ± 1.6	105.5 ± 1.6	
KKC1_14.1	0.00	457	302	0.68	59.14 ± 1.29	0.0440 ± 0.0027	108.1 ± 2.3	108.1 ± 2.3	
KKC1_15.1	0.76	354	255	0.74	59.22 ± 1.57	0.0429 ± 0.0090	107.9 ± 2.8	108.7 ± 2.7	
KKC1_16.1	1.93	253	208	0.84	63.96 ± 1.94	0.0379 ± 0.0114	100.0 ± 3.0	101.3 ± 2.9	
KKC1_17.1	0.20	360	173	0.49	63.84 ± 1.49	0.0401 ± 0.0065	100.2 ± 2.3	100.4 ± 2.2	N
KKC1_18.1	0.14	268	229	0.88	59.85 ± 1.77	0.0496 ± 0.0109	106.8 ± 3.1	106.6 ± 2.9	
KKC1_19.1	0.29	439	167	0.39	60.40 ± 1.29	0.0481 ± 0.0052	105.8 ± 2.2	105.9 ± 2.2	
KKC1_20.1	0.04	912	336	0.38	60.31 ± 1.08	0.0472 ± 0.0038	106.0 ± 1.9	106.1 ± 1.8	
KKC1_21.1	0.00	174	98	0.58	59.72 ± 1.71	0.0451 ± 0.0055	107.1 ± 3.0	107.1 ± 3.0	
KKC1_21.2	0.15	947	391	0.42	59.87 ± 1.03	0.0447 ± 0.0038	106.8 ± 1.8	107.0 ± 1.8	
KKC1_22.1	0.00	487	351	0.74	62.63 ± 1.23	0.0486 ± 0.0030	102.1 ± 2.0	102.0 ± 2.0	
KKC1_22.2	0.56	452	209	0.47	57.65 ± 1.25	0.0452 ± 0.0057	110.9 ± 2.4	111.3 ± 2.4	
KKC1_23.1	1.00	216	128	0.61	63.06 ± 1.82	0.0412 ± 0.0097	101.4 ± 2.9	102.3 ± 2.8	
KKC1_24.1	0.00	231	137	0.61	61.06 ± 1.58	0.0423 ± 0.0044	104.7 ± 2.7	104.7 ± 2.7	
KKC1_25.1	0.35	703	475	0.69	62.15 ± 1.14	0.0479 ± 0.0054	102.9 ± 1.9	102.9 ± 1.8	
KKC1_25.2	0.52	418	141	0.35	61.54 ± 1.45	0.0464 ± 0.0058	103.9 ± 2.4	104.1 ± 2.4	
KKC1_26.1	0.00	633	413	0.67	61.10 ± 1.23	0.0443 ± 0.0027	104.7 ± 2.1	104.7 ± 2.1	
KKC1_27.1	0.00	604	458	0.78	60.26 ± 1.10	0.0458 ± 0.0026	106.1 ± 1.9	106.1 ± 1.9	
KKC1_28.1	0.12	832	163	0.20	60.72 ± 1.12	0.0484 ± 0.0030	105.3 ± 1.9	105.3 ± 1.9	
KKC1_28.2	0.19	595	230	0.40	60.79 ± 1.34	0.0445 ± 0.0048	105.2 ± 2.3	105.4 ± 2.3	
KKC1_29.1	0.00	677	711	1.08	59.19 ± 1.01	0.0487 ± 0.0025	108.0 ± 1.8	107.9 ± 1.9	
KKC1_29.2	0.00	515	191	0.38	61.33 ± 1.18	0.0539 ± 0.0033	104.3 ± 2.0	103.5 ± 2.0	
KKC1_30.1	0.00	642	258	0.41	58.16 ± 1.23	0.0578 ± 0.0030	109.9 ± 2.3	108.6 ± 2.3	D, N
KKC1_31.1	0.00	336	194	0.59	59.17 ± 1.33	0.0478 ± 0.0040	108.0 ± 2.4	108.0 ± 2.4	
KKC1_31.2	1.06	2736	584	0.22	62.64 ± 1.05	0.0431 ± 0.0031	102.1 ± 1.7	102.7 ± 1.7	
KKC1_32.1	0.65	574	389	0.70	61.69 ± 1.29	0.0446 ± 0.0071	103.7 ± 2.2	104.1 ± 2.1	
KKC1_32.2	0.00	283	54	0.20	59.26 ± 1.62	0.0432 ± 0.0040	107.9 ± 2.9	107.9 ± 2.9	
KKC1_33.1	0.00	284	101	0.36	60.73 ± 1.57	0.0506 ± 0.0041	105.3 ± 2.7	105.0 ± 2.7	
Kikuchi granite (KKC2)									
KKC2_01.1	0.61	313	150	0.49	65.63 ± 1.84	0.0539 ± 0.0084	97.5 ± 2.7	96.8 ± 2.7	N
KKC2_02.1	1.27	231	78	0.35	62.69 ± 1.87	0.0382 ± 0.0088	102.0 ± 3.0	103.3 ± 3.0	
KKC2_03.1	0.00	1123	288	0.26	61.12 ± 0.90	0.0478 ± 0.0023	104.6 ± 1.5	104.6 ± 1.5	
KKC2_04.1	0.00	994	394	0.41	61.79 ± 1.01	0.0485 ± 0.0022	103.5 ± 1.7	103.4 ± 1.7	
KKC2_05.1	0.00	1158	598	0.53	57.02 ± 0.90	0.0491 ± 0.0024	112.1 ± 1.7	112.0 ± 1.8	
KKC2_06.1	0.00	262	92	0.36	60.37 ± 1.71	0.0488 ± 0.0054	105.9 ± 3.0	105.8 ± 3.1	
KKC2_07.1	0.70	343	154	0.46	60.39 ± 1.69	0.0418 ± 0.0077	105.9 ± 2.9	106.6 ± 2.9	
KKC2_08.1	0.00	605	174	0.29	60.66 ± 1.22	0.0484 ± 0.0030	105.4 ± 2.1	105.4 ± 2.1	
KKC2_09.1	0.00	364	127	0.36	60.68 ± 1.27	0.0572 ± 0.0043	105.4 ± 2.2	104.2 ± 2.2	D, N
KKC2_10.1	0.00	1098	497	0.46	61.02 ± 1.03	0.0484 ± 0.0019	104.8 ± 1.7	104.8 ± 1.8	
KKC2_11.1	0.33	380	151	0.41	60.56 ± 1.62	0.0425 ± 0.0064	105.6 ± 2.8	105.9 ± 2.8	
KKC2_12.1	0.00	223	88	0.40	62.69 ± 1.69	0.0486 ± 0.0054	102.0 ± 2.7	102.0 ± 2.8	
KKC2_12.2	0.00	220	74	0.34	57.28 ± 1.69	0.0385 ± 0.0053	111.6 ± 3.3	111.6 ± 3.3	
KKC2_13.1	0.00	373	211	0.58	60.20 ± 1.40	0.0452 ± 0.0037	106.2 ± 2.5	106.2 ± 2.5	
KKC2_14.1	0.02	1073	289	0.28	53.38 ± 0.98	0.0505 ± 0.0030	119.7 ± 2.2	119.3 ± 2.2	
KKC2_15.1	0.00	556	285	0.53	61.06 ± 1.22	0.0439 ± 0.0032	104.7 ± 2.1	104.7 ± 2.1	
KKC2_16.1	0.16	1430	260	0.19	62.64 ± 1.10	0.0455 ± 0.0030	102.1 ± 1.8	102.3 ± 1.8	
KKC2_17.1	0.34	567	406	0.73	63.75 ± 1.55	0.0420 ± 0.0065	100.3 ± 2.4	100.7 ± 2.3	
KKC2_18.1	0.07	305	99	0.33	59.06 ± 1.63	0.0468 ± 0.0062	108.2 ± 3.0	108.3 ± 2.9	
KKC2_19.1	0.27	641	169	0.27	57.66 ± 1.22	0.0451 ± 0.0044	110.8 ± 2.3	111.1 ± 2.3	
KKC2_19.2	0.00	167	59	0.36	59.31 ± 1.72	0.0445 ± 0.0048	107.8 ± 3.1	107.8 ± 3.1	
KKC2_20.1	0.00	532	280	0.54	62.04 ± 1.18	0.0480 ± 0.0033	103.1 ± 1.9	103.1 ± 1.9	
KKC2_21.1	0.24	623	202	0.33	60.25 ± 1.11	0.0488 ± 0.0047	106.1 ± 1.9	106.0 ± 1.9	
KKC2_22.1	0.26	324	128	0.40	65.20 ± 1.69	0.0472 ± 0.0063	98.1 ± 2.5	98.2 ± 2.5	
KKC2_23.1	0.08	224	85	0.39	60.49 ± 1.64	0.0553 ± 0.0075	105.7 ± 2.8	104.8 ± 2.8	
KKC2_24.1	0.70	472	252	0.55	63.79 ± 1.49	0.0439 ± 0.0063	100.3 ± 2.3	100.8 ± 2.3	
KKC2_25.1	0.00	695	290	0.43	61.63 ± 1.11	0.0464 ± 0.0029	103.8 ± 1.9	103.8 ± 1.9	
KKC2_26.1	0.00	931	264	0.29	58.13 ± 0.93	0.0501 ± 0.0024	109.9 ± 1.7	109.7 ± 1.8	
KKC2_26.2	0.00	214	74	0.36	60.21 ± 1.89	0.0451 ± 0.0062	106.2 ± 3.3	106.2 ± 3.3	

Table 1. Continued

Labels	$^{206}Pb_c$ (1) (%)	U (ppm)	Th (ppm)	Th/U	$^{238}U/^{206}Pb^*$ (1)	$^{207}Pb^*/^{206}Pb^*$ (1)	$^{238}U/^{206}Pb^*$ age (1) (Ma)	$^{238}U/^{206}Pb^*$ age (2) (Ma)	Remarks
KKC2_27.1	0.00	312	172	0.57	59.24 ± 1.65	0.0489 ± 0.0043	107.9 ± 3.0	107.8 ± 3.0	
KKC2_28.1	0.00	132	64	0.50	63.94 ± 2.15	0.0462 ± 0.0071	100.0 ± 3.3	100.0 ± 3.3	
KKC2_28.2	0.00	556	190	0.35	56.42 ± 1.17	0.0479 ± 0.0025	113.3 ± 2.3	113.3 ± 2.3	
KKC2_29.1	0.00	271	109	0.41	58.96 ± 1.60	0.0481 ± 0.0040	108.4 ± 2.9	108.4 ± 2.9	
KKC2_30.1	0.18	710	353	0.51	62.43 ± 1.22	0.0492 ± 0.0045	102.4 ± 2.0	102.3 ± 2.0	
KKC2_30.2	0.00	231	78	0.35	59.61 ± 1.67	0.0541 ± 0.0057	107.2 ± 3.0	106.4 ± 3.1	
KKC2_31.1	0.00	299	101	0.35	55.72 ± 1.44	0.0485 ± 0.0045	114.7 ± 2.9	114.7 ± 3.0	N
KKC2_32.1	0.00	320	117	0.38	59.23 ± 1.72	0.0417 ± 0.0043	107.9 ± 3.1	107.9 ± 3.1	
KKC2_33.1	2.15	574	200	0.36	61.29 ± 1.42	0.0394 ± 0.0047	104.3 ± 2.4	105.5 ± 2.4	
KKC2_33.2	0.00	2596	1169	0.46	58.48 ± 0.87	0.0470 ± 0.0014	109.3 ± 1.6	109.3 ± 1.6	
Tamana granodiorite (TMN1)									
TMN1_01.1	0.00	310	123	0.41	60.09 ± 1.66	0.0470 ± 0.0036	106.4 ± 2.9	106.4 ± 2.9	
TMN1_01.2	0.00	725	548	0.78	61.17 ± 1.09	0.0487 ± 0.0029	104.5 ± 1.9	104.5 ± 1.9	
TMN1_02.1	0.00	568	234	0.42	60.15 ± 1.17	0.0438 ± 0.0029	106.3 ± 2.0	106.3 ± 2.0	
TMN1_03.1	0.00	478	260	0.56	61.95 ± 1.30	0.0518 ± 0.0037	103.2 ± 2.1	102.7 ± 2.2	
TMN1_03.2	0.10	735	171	0.24	61.19 ± 1.12	0.0465 ± 0.0036	104.5 ± 1.9	104.6 ± 1.9	
TMN1_04.1	0.00	375	249	0.68	58.43 ± 1.24	0.0458 ± 0.0038	109.4 ± 2.3	109.4 ± 2.3	
TMN1_04.2	0.00	506	203	0.41	61.81 ± 1.25	0.0520 ± 0.0035	103.5 ± 2.1	103.0 ± 2.1	
TMN1_05.1	0.44	379	126	0.34	62.08 ± 1.63	0.0432 ± 0.0057	103.0 ± 2.7	103.5 ± 2.7	
TMN1_06.1	0.36	518	239	0.47	59.22 ± 1.31	0.0390 ± 0.0053	107.9 ± 2.4	108.3 ± 2.3	
TMN1_06.2	0.00	372	145	0.40	59.40 ± 1.47	0.0415 ± 0.0036	107.6 ± 2.6	107.6 ± 2.6	
TMN1_07.1	1.41	340	258	0.78	60.80 ± 1.56	0.0420 ± 0.0095	105.2 ± 2.7	106.0 ± 2.6	
TMN1_07.2	0.00	281	87	0.32	61.96 ± 1.57	0.0460 ± 0.0041	103.2 ± 2.6	103.2 ± 2.6	
TMN1_08.1	0.24	209	76	0.38	60.83 ± 1.99	0.0492 ± 0.0084	105.1 ± 3.4	105.0 ± 3.4	
TMN1_09.1	0.00	542	170	0.32	58.44 ± 1.35	0.0478 ± 0.0030	109.4 ± 2.5	109.4 ± 2.5	
TMN1_09.2	0.00	472	168	0.36	58.13 ± 1.31	0.0500 ± 0.0034	110.0 ± 2.5	109.7 ± 2.5	
TMN1_10.1	0.00	869	463	0.55	60.50 ± 1.12	0.0549 ± 0.0029	105.7 ± 1.9	104.8 ± 2.0	D, N
TMN1_10.2	0.33	433	166	0.39	57.90 ± 1.44	0.0540 ± 0.0058	110.4 ± 2.7	109.6 ± 2.7	
TMN1_11.1	0.00	437	211	0.49	57.68 ± 1.33	0.0476 ± 0.0036	110.8 ± 2.5	110.8 ± 2.5	
TMN1_11.2	0.25	443	177	0.41	62.14 ± 1.51	0.0568 ± 0.0063	102.9 ± 2.5	101.8 ± 2.5	
TMN1_12.1	0.00	805	256	0.33	56.89 ± 1.05	0.0512 ± 0.0025	112.3 ± 2.1	111.9 ± 2.1	N
TMN1_13.1	0.00	221	84	0.39	59.25 ± 1.60	0.0429 ± 0.0055	107.9 ± 2.9	107.9 ± 2.9	
TMN1_13.2	0.00	438	201	0.47	60.45 ± 1.41	0.0491 ± 0.0033	105.8 ± 2.5	105.6 ± 2.5	
TMN1_14.1	0.00	481	581	1.24	23.08 ± 0.39	0.0502 ± 0.0021	273.5 ± 4.5	273.5 ± 4.5	
TMN1_14.2	0.00	559	148	0.27	60.54 ± 1.19	0.0469 ± 0.0030	105.6 ± 2.1	105.6 ± 2.1	
TMN1_15.1	0.00	401	187	0.48	59.37 ± 1.28	0.0484 ± 0.0038	107.7 ± 2.3	107.7 ± 2.4	
TMN1_15.2	1.11	397	172	0.44	58.26 ± 1.42	0.0513 ± 0.0074	109.7 ± 2.7	109.3 ± 2.6	
TMN1_16.1	0.00	231	87	0.38	58.72 ± 1.74	0.0588 ± 0.0065	108.9 ± 3.2	107.4 ± 3.3	
TMN1_17.1	1.66	531	225	0.43	62.29 ± 1.26	0.0453 ± 0.0060	102.7 ± 2.1	103.0 ± 2.1	
TMN1_18.1	0.00	563	145	0.26	61.14 ± 1.32	0.0524 ± 0.0033	104.6 ± 2.2	104.0 ± 2.3	
TMN1_19.1	0.00	419	108	0.26	59.30 ± 1.45	0.0498 ± 0.0043	107.8 ± 2.6	107.6 ± 2.7	
TMN1_20.1	1.45	241	78	0.33	61.50 ± 1.85	0.0348 ± 0.0074	104.0 ± 3.1	105.5 ± 3.1	
TMN1_21.1	0.00	569	298	0.54	57.41 ± 1.33	0.0479 ± 0.0027	111.3 ± 2.5	111.3 ± 2.5	
TMN1_21.2	0.41	266	89	0.35	59.71 ± 1.71	0.0481 ± 0.0078	107.1 ± 3.0	107.1 ± 3.0	
TMN1_22.1	0.65	1328	813	0.63	58.37 ± 1.12	0.0490 ± 0.0045	109.5 ± 2.1	109.4 ± 2.0	
TMN1_22.2	0.00	475	169	0.36	56.06 ± 1.29	0.0610 ± 0.0042	114.0 ± 2.6	112.2 ± 2.6	D, N
TMN1_23.1	0.00	741	435	0.60	59.95 ± 1.19	0.0499 ± 0.0029	106.6 ± 2.1	106.4 ± 2.1	
TMN1_24.1	0.00	401	133	0.34	62.14 ± 1.40	0.0438 ± 0.0036	102.9 ± 2.3	102.9 ± 2.3	
TMN1_25.1	0.40	303	145	0.49	64.06 ± 1.71	0.0450 ± 0.0077	99.9 ± 2.6	100.2 ± 2.6	
TMN1_25.2	0.01	354	133	0.39	62.45 ± 1.42	0.0482 ± 0.0059	102.4 ± 2.3	102.4 ± 2.3	
TMN1_26.1	0.00	451	155	0.35	59.80 ± 1.23	0.0426 ± 0.0032	106.9 ± 2.2	106.9 ± 2.2	
TMN1_27.1	0.00	799	469	0.60	60.77 ± 1.08	0.0484 ± 0.0025	105.2 ± 1.9	105.2 ± 1.9	
TMN1_28.1	0.17	1040	541	0.53	61.75 ± 1.07	0.0499 ± 0.0040	103.6 ± 1.8	103.3 ± 1.8	
TMN1_29.1	0.00	972	761	0.80	63.71 ± 1.07	0.0499 ± 0.0025	100.4 ± 1.7	100.2 ± 1.7	N
TMN1_29.2	0.00	386	141	0.37	62.29 ± 1.57	0.0569 ± 0.0037	102.7 ± 2.6	101.5 ± 2.6	D, N
TMN1_30.1	0.00	168	45	0.27	63.62 ± 2.09	0.0436 ± 0.0056	100.5 ± 3.3	100.5 ± 3.3	
TMN1_31.1	0.21	622	307	0.51	64.07 ± 1.35	0.0476 ± 0.0052	99.8 ± 2.1	99.9 ± 2.1	N
TMN1_31.2	0.09	720	219	0.31	60.25 ± 1.12	0.0510 ± 0.0044	106.1 ± 2.0	105.7 ± 2.0	
TMN1_32.1	0.00	1799	1821	1.04	60.71 ± 0.96	0.0512 ± 0.0020	105.3 ± 1.6	104.9 ± 1.7	
TMN1_32.2	0.56	351	110	0.32	60.97 ± 1.53	0.0421 ± 0.0059	104.9 ± 2.6	105.5 ± 2.6	
TMN1_33.1	0.00	545	193	0.36	59.58 ± 1.16	0.0506 ± 0.0036	107.3 ± 2.1	107.0 ± 2.1	
TMN1_34.1	0.47	245	115	0.48	60.64 ± 1.76	0.0435 ± 0.0089	105.4 ± 3.0	105.9 ± 2.9	
TMN1_34.2	0.03	534	131	0.25	58.16 ± 1.20	0.0489 ± 0.0042	109.9 ± 2.2	109.8 ± 2.3	
TMN1_35.1	0.00	376	197	0.54	60.60 ± 1.48	0.0535 ± 0.0042	105.5 ± 2.6	104.8 ± 2.6	
TMN1_35.2	0.00	483	143	0.30	61.98 ± 1.31	0.0497 ± 0.0034	103.2 ± 2.2	103.0 ± 2.2	
TMN1_36.1	0.00	708	300	0.43	62.31 ± 1.30	0.0491 ± 0.0029	102.6 ± 2.1	102.5 ± 2.2	
TMN1_36.2	0.00	335	96	0.29	60.74 ± 1.48	0.0420 ± 0.0044	105.3 ± 2.5	105.3 ± 2.5	
TMN1_37.1	1.37	270	82	0.31	59.57 ± 1.57	0.0435 ± 0.0076	107.3 ± 2.8	107.9 ± 2.8	
TMN1_38.1	0.00	99	106	1.10	60.84 ± 2.39	0.0603 ± 0.0103	105.1 ± 4.1	103.5 ± 4.3	
TMN1_38.2	0.46	386	148	0.39	59.33 ± 1.52	0.0459 ± 0.0060	107.8 ± 2.7	108.1 ± 2.7	
Tamana granodiorite (TMN2)									
TMN2_01.1	0.00	392	146	0.38	60.31 ± 1.17	0.0488 ± 0.0034	106.0 ± 2.0	105.9 ± 2.1	

Table 1. Continued

Labels	$^{206}Pb_c$ $^{(1)}$ (%)	U (ppm)	Th (ppm)	Th/U	$^{238}U/^{206}Pb^{*}$ $^{(1)}$	$^{207}Pb^{*}/^{206}Pb^{*}$ $^{(1)}$	$^{238}U/^{206}Pb^{*}$ age $^{(1)}$ (Ma)	$^{238}U/^{206}Pb^{*}$ age $^{(2)}$ (Ma)	Remarks
TMN2_01.2	0.00	337	98	0.30	64.28 ± 1.48	0.0472 ± 0.0035	99.5 ± 2.3	99.5 ± 2.3	
TMN2_02.1	0.00	477	231	0.50	60.50 ± 1.16	0.0523 ± 0.0032	105.7 ± 2.0	105.1 ± 2.0	
TMN2_03.1	0.89	345	155	0.46	43.86 ± 1.05	0.0403 ± 0.0058	145.3 ± 3.4	146.6 ± 3.4	N
TMN2_03.2	0.76	254	88	0.35	59.23 ± 1.39	0.0448 ± 0.0055	107.9 ± 2.5	108.4 ± 2.5	
TMN2_04.1	0.27	569	250	0.45	63.48 ± 1.30	0.0476 ± 0.0045	100.8 ± 2.0	100.8 ± 2.0	
TMN2_04.2	0.00	201	67	0.34	62.11 ± 1.84	0.0492 ± 0.0050	103.0 ± 3.0	102.8 ± 3.1	
TMN2_05.1	0.00	907	617	0.70	59.25 ± 1.06	0.0495 ± 0.0026	107.9 ± 1.9	107.7 ± 1.9	
TMN2_06.1	0.68	366	148	0.41	58.70 ± 1.38	0.0448 ± 0.0062	108.9 ± 2.5	109.4 ± 2.5	
TMN2_07.1	2.01	299	117	0.40	59.20 ± 1.40	0.0545 ± 0.0066	108.0 ± 2.5	107.1 ± 2.5	
TMN2_07.2	0.86	354	139	0.40	59.54 ± 1.52	0.0382 ± 0.0057	107.4 ± 2.7	108.3 ± 2.7	
TMN2_08.1	0.00	293	116	0.41	54.58 ± 1.34	0.0526 ± 0.0047	117.0 ± 2.8	116.4 ± 2.9	N
TMN2_08.2	0.00	370	141	0.39	58.74 ± 1.13	0.0492 ± 0.0043	108.8 ± 2.1	108.7 ± 2.2	
TMN2_09.1	0.60	1053	448	0.44	59.99 ± 1.13	0.0474 ± 0.0040	106.6 ± 2.0	106.7 ± 2.0	
TMN2_10.1	0.08	638	320	0.51	58.78 ± 1.06	0.0454 ± 0.0047	108.7 ± 1.9	108.8 ± 1.9	
TMN2_11.1	0.00	479	214	0.46	62.41 ± 1.11	0.0476 ± 0.0034	102.5 ± 1.8	102.5 ± 1.8	
TMN2_12.1	0.00	352	114	0.33	55.13 ± 1.28	0.0465 ± 0.0034	115.9 ± 2.7	115.9 ± 2.7	N
TMN2_13.1	0.64	379	196	0.53	61.31 ± 1.26	0.0598 ± 0.0064	104.3 ± 2.1	102.8 ± 2.1	
TMN2_14.1	0.08	322	140	0.45	60.90 ± 1.50	0.0482 ± 0.0062	105.0 ± 2.6	105.0 ± 2.6	
TMN2_15.1	0.42	718	509	0.73	59.95 ± 1.01	0.0450 ± 0.0052	106.6 ± 1.8	107.1 ± 1.8	
TMN2_16.1	0.00	703	575	0.84	60.87 ± 1.07	0.0489 ± 0.0026	105.0 ± 1.8	104.9 ± 1.9	
TMN2_16.2	0.29	443	261	0.60	60.19 ± 1.27	0.0492 ± 0.0062	106.2 ± 2.2	106.1 ± 2.2	
TMN2_17.1	0.00	648	512	0.81	60.51 ± 1.16	0.0509 ± 0.0031	105.7 ± 2.0	105.3 ± 2.0	
TMN2_18.1	3.31	465	218	0.48	61.01 ± 1.32	0.0399 ± 0.0075	104.8 ± 2.3	105.9 ± 2.2	
TMN2_18.2	0.00	796	560	0.72	59.75 ± 1.15	0.0497 ± 0.0028	107.0 ± 2.0	106.8 ± 2.1	
TMN2_19.1	0.32	289	103	0.37	60.21 ± 1.65	0.0488 ± 0.0066	106.2 ± 2.9	106.1 ± 2.9	
TMN2_19.2	0.00	596	307	0.53	61.46 ± 1.19	0.0499 ± 0.0033	104.0 ± 2.0	103.8 ± 2.0	
TMN2_20.1	0.91	400	131	0.34	53.65 ± 1.36	0.0406 ± 0.0054	119.1 ± 3.0	120.1 ± 3.0	N
TMN2_20.2	0.86	356	90	0.26	61.59 ± 1.62	0.0450 ± 0.0063	103.8 ± 2.7	104.2 ± 2.7	
TMN2_21.1	0.00	722	415	0.59	61.54 ± 1.27	0.0465 ± 0.0024	103.9 ± 2.1	103.9 ± 2.1	
TMN2_21.2	0.00	427	229	0.55	57.46 ± 1.22	0.0496 ± 0.0034	111.2 ± 2.3	111.0 ± 2.4	
TMN2_22.1	0.00	829	179	0.22	59.31 ± 1.11	0.0491 ± 0.0025	107.8 ± 2.0	107.7 ± 2.0	
TMN2_22.2	0.00	353	177	0.51	59.40 ± 1.50	0.0466 ± 0.0038	107.6 ± 2.7	107.6 ± 2.7	
TMN2_23.1	0.00	404	174	0.44	61.17 ± 1.36	0.0526 ± 0.0041	104.5 ± 2.3	103.9 ± 2.4	
TMN2_24.1	0.00	398	137	0.35	63.20 ± 1.47	0.0447 ± 0.0034	101.2 ± 2.3	101.2 ± 2.3	
TMN2_25.1	0.00	743	269	0.37	56.26 ± 1.15	0.0492 ± 0.0026	113.6 ± 2.3	113.4 ± 2.3	N
TMN2_25.2	0.00	346	93	0.28	60.07 ± 1.44	0.0530 ± 0.0047	106.4 ± 2.5	105.8 ± 2.6	
TMN2_26.1	0.57	389	141	0.37	59.62 ± 1.56	0.0466 ± 0.0052	107.2 ± 2.8	107.4 ± 2.8	
TMN2_27.1	0.00	775	422	0.56	62.14 ± 1.17	0.0489 ± 0.0029	102.9 ± 1.9	102.8 ± 2.0	
TMN2_28.1	0.00	601	112	0.19	54.69 ± 1.11	0.0482 ± 0.0029	116.8 ± 2.3	116.8 ± 2.3	N
TMN2_29.1	0.00	793	470	0.61	63.09 ± 1.36	0.0601 ± 0.0055	101.4 ± 2.2	99.9 ± 2.1	D, N
TMN2_30.1	0.00	774	468	0.62	61.47 ± 1.16	0.0550 ± 0.0029	104.0 ± 2.0	103.1 ± 2.0	D, N
TMN2_30.2	0.28	324	127	0.40	60.06 ± 1.60	0.0361 ± 0.0060	106.4 ± 2.8	106.7 ± 2.7	
TMN2_31.1	0.00	338	129	0.39	59.70 ± 1.34	0.0645 ± 0.0047	107.1 ± 2.4	104.9 ± 2.4	D, N
TMN2_32.1	0.47	789	214	0.28	62.00 ± 1.24	0.0467 ± 0.0041	103.1 ± 2.1	103.3 ± 2.0	
TMN2_32.2	0.00	369	139	0.39	59.80 ± 1.36	0.0473 ± 0.0034	106.9 ± 2.4	106.9 ± 2.4	
Tsutsugatake granite (TGT1)									
TGT1_01.1	0.00	704	500	0.73	57.83 ± 0.98	0.0430 ± 0.0027	110.5 ± 1.8	110.5 ± 1.8	
TGT1_01.2	0.07	1427	281	0.20	61.17 ± 1.03	0.0469 ± 0.0023	104.5 ± 1.7	104.6 ± 1.7	
TGT1_02.1	0.00	593	415	0.72	59.74 ± 1.13	0.0448 ± 0.0029	107.0 ± 2.0	107.0 ± 2.0	
TGT1_03.1	0.49	306	97	0.32	62.06 ± 1.59	0.0445 ± 0.0065	103.1 ± 2.6	103.5 ± 2.6	
TGT1_04.1	0.00	568	374	0.68	60.00 ± 1.23	0.0442 ± 0.0027	106.6 ± 2.2	106.6 ± 2.2	
TGT1_05.1	0.00	488	239	0.50	59.64 ± 1.26	0.0461 ± 0.0033	107.2 ± 2.3	107.2 ± 2.3	
TGT1_06.1	0.00	690	288	0.43	61.27 ± 1.07	0.0510 ± 0.0033	104.4 ± 1.8	104.0 ± 1.9	
TGT1_06.2	0.14	2070	128	0.06	60.26 ± 0.83	0.0488 ± 0.0019	106.1 ± 1.5	106.0 ± 1.5	
TGT1_07.1	0.89	287	173	0.62	62.87 ± 1.74	0.0445 ± 0.0081	101.7 ± 2.8	102.2 ± 2.7	
TGT1_07.2	0.00	950	167	0.18	62.57 ± 1.02	0.0461 ± 0.0020	102.2 ± 1.6	102.2 ± 1.6	
TGT1_08.1	0.38	721	221	0.31	62.57 ± 1.20	0.0448 ± 0.0049	102.2 ± 1.9	102.6 ± 1.9	
TGT1_09.1	0.00	116	81	0.71	62.94 ± 2.65	0.0577 ± 0.0093	101.6 ± 4.2	100.4 ± 4.4	
TGT1_10.1	0.65	462	178	0.39	60.89 ± 1.30	0.0457 ± 0.0056	105.0 ± 2.2	105.3 ± 2.2	
TGT1_10.2	0.22	445	138	0.32	60.20 ± 1.45	0.0507 ± 0.0049	106.2 ± 2.5	105.9 ± 2.5	
TGT1_11.1	0.00	2036	1073	0.54	58.27 ± 0.87	0.0477 ± 0.0016	109.7 ± 1.6	109.7 ± 1.6	
TGT1_11.2	0.19	688	111	0.17	59.11 ± 1.11	0.0458 ± 0.0032	108.1 ± 2.0	108.3 ± 2.0	
TGT1_12.1	0.07	661	393	0.61	57.65 ± 1.08	0.0423 ± 0.0048	110.9 ± 2.1	110.9 ± 2.0	
TGT1_13.1	0.69	356	412	1.19	62.11 ± 1.79	0.0404 ± 0.0107	103.0 ± 2.9	103.7 ± 2.7	
TGT1_14.1	0.00	133	90	0.70	61.01 ± 2.22	0.0514 ± 0.0083	104.8 ± 3.8	104.4 ± 3.9	
TGT1_15.1	0.68	74	60	0.82	60.17 ± 2.99	0.0409 ± 0.0192	106.3 ± 5.2	107.0 ± 4.8	
TGT1_16.1	0.00	109	82	0.77	60.92 ± 2.57	0.0409 ± 0.0073	105.0 ± 4.4	105.0 ± 4.4	
TGT1_17.1	0.00	119	72	0.62	60.05 ± 2.04	0.0539 ± 0.0079	106.5 ± 3.6	105.7 ± 3.7	
TGT1_17.2	0.19	703	139	0.20	57.28 ± 1.01	0.0460 ± 0.0036	111.6 ± 2.0	111.8 ± 1.9	N
TGT1_18.1	0.70	602	221	0.38	60.39 ± 1.10	0.0470 ± 0.0052	105.9 ± 1.9	106.0 ± 1.9	
TGT1_18.2	0.43	2220	648	0.30	61.29 ± 0.97	0.0496 ± 0.0023	104.3 ± 1.6	104.1 ± 1.6	
TGT1_19.1	0.03	828	341	0.42	58.85 ± 1.03	0.0481 ± 0.0039	108.6 ± 1.9	108.6 ± 1.9	
TGT1_20.1	0.01	654	256	0.40	59.19 ± 1.12	0.0436 ± 0.0042	108.0 ± 2.0	108.0 ± 2.0	

Table 1. Continued

Labels	$^{206}Pb_c$ (1) (%)	U (ppm)	Th (ppm)	Th/U	$^{238}U/^{206}Pb^*$ (1)	$^{207}Pb^*/^{206}Pb^*$ (1)	$^{238}U/^{206}Pb^*$ age (1) (Ma)	$^{238}U/^{206}Pb^*$ age (2) (Ma)	Remarks
TGT1_21.1	0.02	446	103	0.24	57.76 ± 1.29	0.0508 ± 0.0051	110.7 ± 2.4	110.3 ± 2.5	
TGT1_22.1	0.00	380	184	0.50	61.68 ± 1.41	0.0436 ± 0.0033	103.7 ± 2.3	103.7 ± 2.3	
TGT1_23.1	0.40	119	105	0.91	56.76 ± 2.22	0.0497 ± 0.0151	112.6 ± 4.4	112.4 ± 4.2	
TGT1_24.1	0.01	360	119	0.34	60.14 ± 1.34	0.0539 ± 0.0056	106.3 ± 2.3	105.6 ± 2.3	
TGT1_24.2	0.00	2104	678	0.33	60.97 ± 0.86	0.0465 ± 0.0013	104.9 ± 1.5	104.9 ± 1.5	
TGT1_25.1	0.42	420	129	0.32	60.14 ± 1.29	0.0532 ± 0.0051	106.3 ± 2.3	105.6 ± 2.3	
TGT1_26.1	0.00	110	74	0.69	55.51 ± 2.01	0.0294 ± 0.0053	115.1 ± 4.1	115.1 ± 4.1	D, N
TGT1_27.1	0.00	112	103	0.95	63.95 ± 2.27	0.0573 ± 0.0074	100.0 ± 3.5	98.9 ± 3.6	

Errors are 1-sigma; Pb_c and Pb^* indicate the common and radiogenic portions, respectively.
Remarks; D: discordant, N: not used for weighted mean age calculation
(1) Common Pb corrected by assuming $^{206}Pb/^{238}U$–$^{208}Pb/^{232}Th$ age-concordance
(2) Common Pb corrected by assuming $^{206}Pb/^{238}U$–$^{207}Pb/^{235}U$ age-concordance

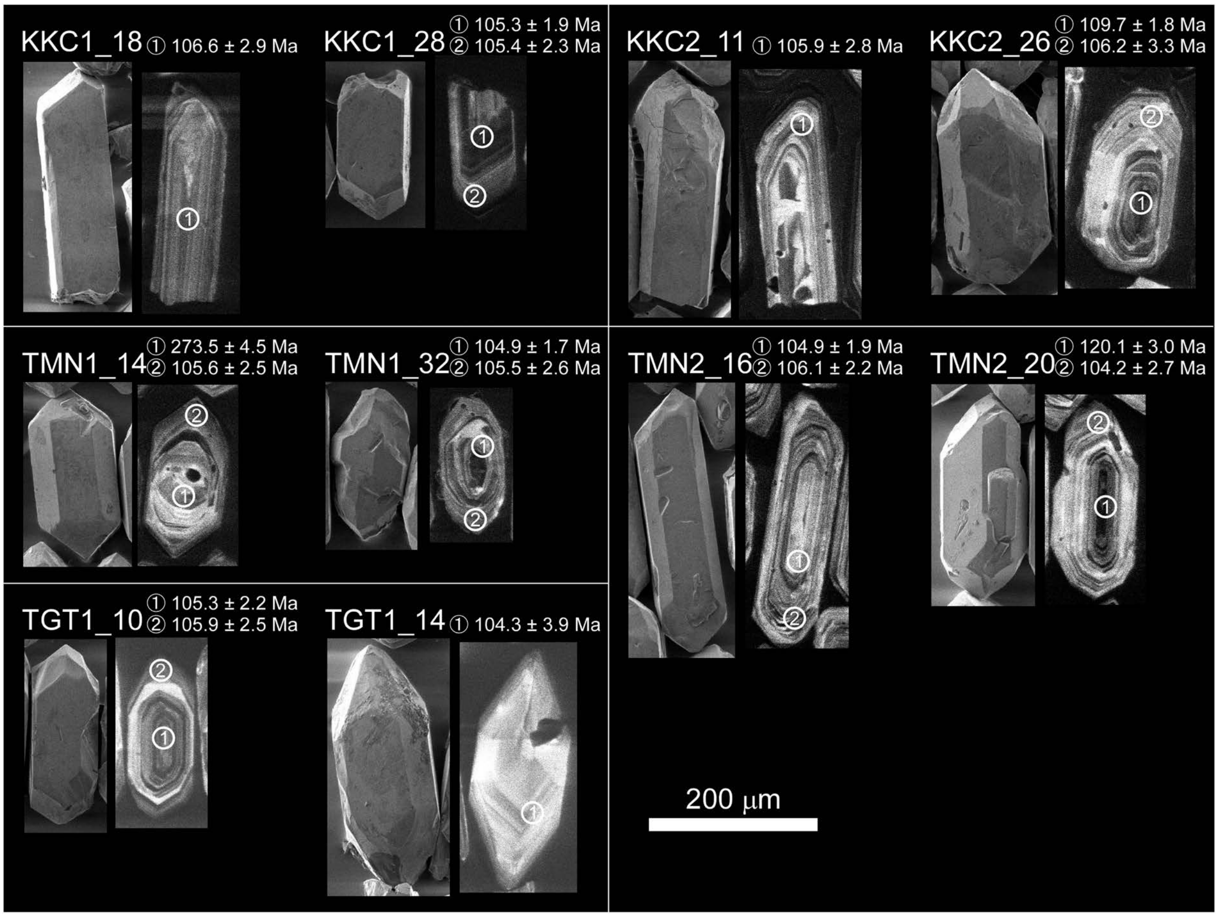

Fig. 3. Morphological secondary electron (SE) images before cement in resin and cathodoluminescence (CL) images of analyzing section of typical zircon grains from the samples. Circles on the images point to analyzed spots by LA-ICP-MS which diameter are 25 μm approx.

National Museum of Nature and Science (http://db.kahaku.go.jp/webmuseum_en/).

KKC1: Kikuchi granite

The sample was collected from north of Lake Hanjaku in the northeastern part of Kikuchi City (lat: N 33°03′32.0″, long: E 130°52′29.0″). This is a medium to coarse grained granite. The major minerals of this rock are quartz, plagioclase, alkali feldspar, biotite, and muscovite. Plagioclase occurs as euhedral to subhedral crystal and exhibits indistinct albite twin and oscillatory zoning. Biotite is partly altered into chlorite. Undulatory extinction is observed in quartz. Zircon and opaque mineral are common accessory minerals. The registration number is 137666.

Most zircon grains are 150 to 300 μm in length, partly rounded with elongation ratio of 1.8 to 3.3.

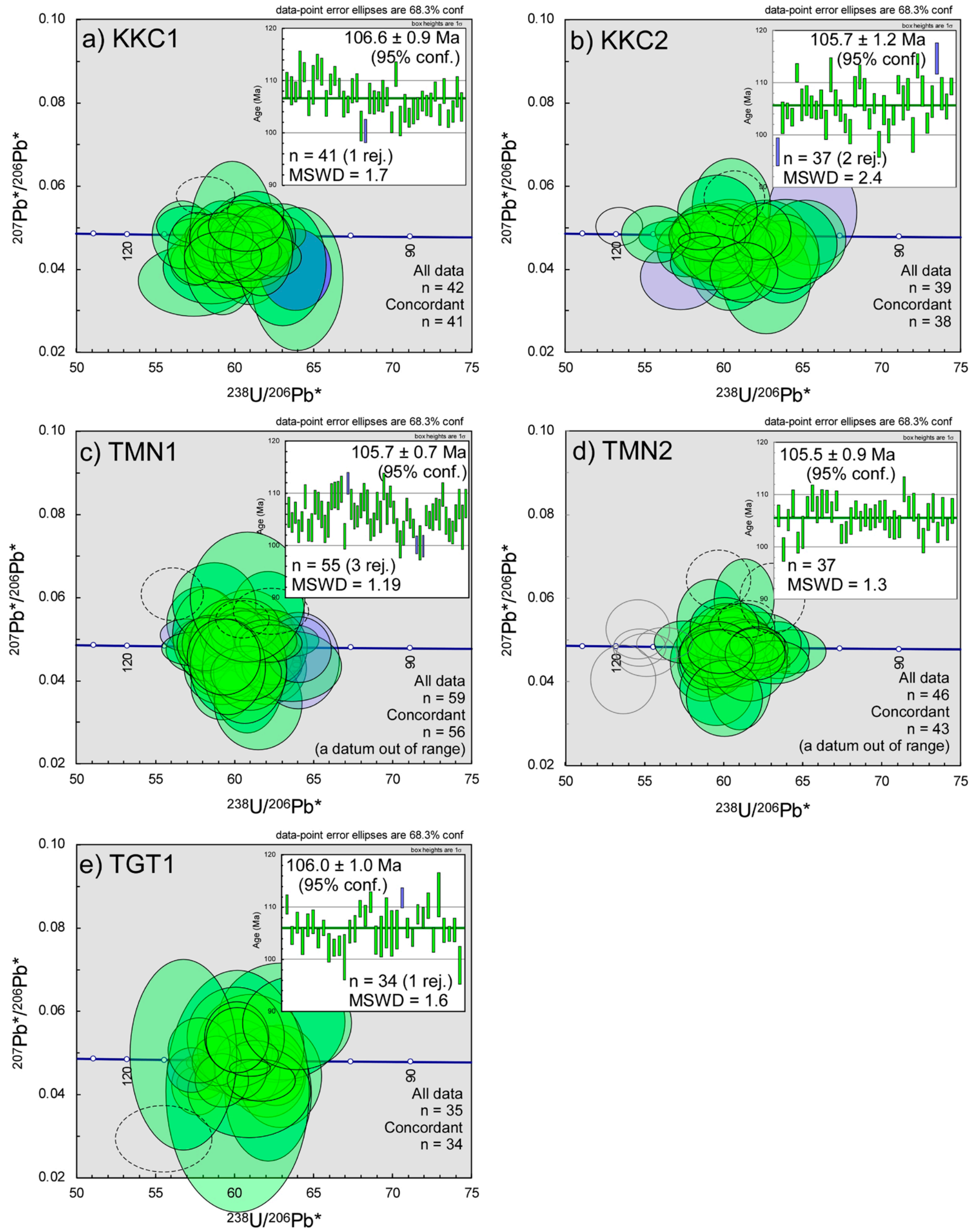

Fig. 4. Tera-Wasserberg U–Pb concordia diagrams and age distribution plot of zircons from the samples.

Their CL images are relatively bright with distinct oscillatory and/or sector zoning. 42 spots from 33 grains were analyzed and the weighted mean age of 41 concordant data indicate 106.6 ± 0.9 Ma (1 datum rejected; MSWD = 1.7).

KKC2: Kikuchi granite

The sample was collected from east of Happogatake in the eastern part of Yamaga City (lat: N33°03′32.0″, long: E 130°47′29.3″). This is a medium grained granite. Microscopic observation is similar to KKC1. The registration number is 137668.

Most zircon grains are 180 to 350 μm in length with prismatic and elongation ratio from 1.8 to 4.0. CL image of the zircons are relatively bright with distinct oscillatory zoning. Although some darker CL cores were observed, there are no age differences beyond the error range. 39 spots from 33 grains were analyzed and 38 data are concordant. After an older datum was excluded, the weighted mean age of 37 data indicates 105.7 ± 1.2 Ma (2 data are rejected; MSWD = 2.4).

TMN1: Tamana granodiorite

The sample was collected from the left side bank of the Hazama River, downstream of the Ryumon Dam (lat: N 33°02′05.4″, long: E 130°50′51.0″).

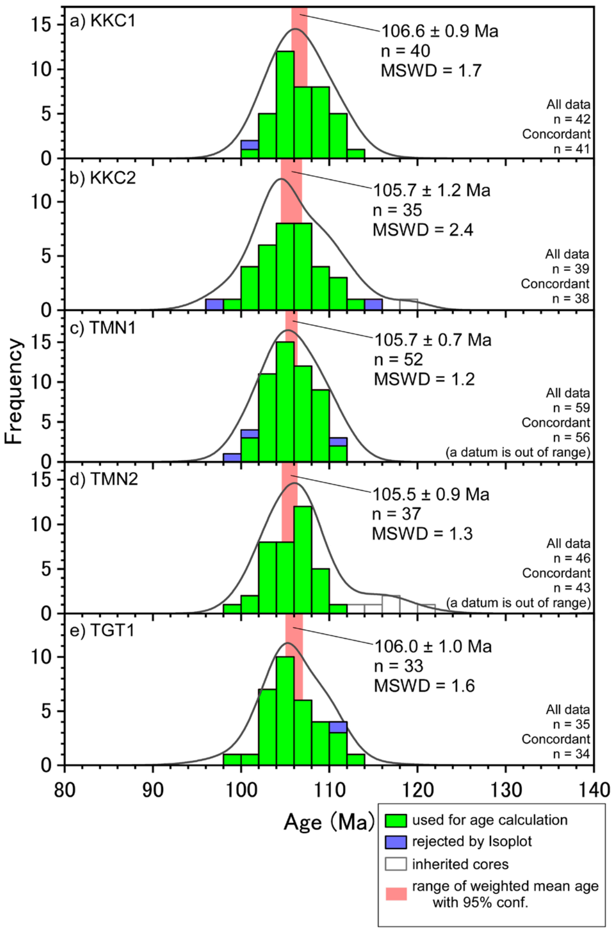

Fig. 5. Probability distribution diagrams and histogram of zircon ages in the samples.

This is a coarse grained granodiorite. The major minerals of this rock are plagioclase, quartz, biotite and amphibole. Plagioclase occurs as euhedral to subhedral crystal and exhibits indistinct albite twin and oscillatory zoning. Undulatory extinction is observed in quartz. Zircon and opaque mineral are common accessory minerals. The registration number is 137667.

Most zircon grains are 150 to 240 μm length with prismatic and elongation ratio from 1.5 to 3.5. CL images are relatively bright with distinct oscillatory zoning. 59 spots from 38 grains were analyzed and 56 data are concordant. After 1 older datum was excluded, the weighted mean age of all concordant data indicates 105.7 ± 0.7 Ma (3 data rejected; MSWD = 1.2).

TMN2: Tamana granodiorite

The sample was collected from the western end part of Yamaga City (lat: N 32°58′40.9″, long: E 130°38′30.3″). This is a medium to coarse grained granodiorite. Microscopic observation is similar to TMN1. The registration number is 137670.

Most zircon grains are 150 to 300 μm length with prismatic and elongation ratio from 2.0 to 3.9. CL images are relatively bright with distinct oscillatory zoning. 48 spots from 27 grains were analyzed and 43 data are concordant. After 5 older data were excluded, the weighted mean age of all 38 data indicates 105.5 ± 0.9 Ma (MSWD = 1.3).

TGT1: Tsutsugatake granite

The sample was collected from the northeastern foot of Mt. Tsutsugatake (lat: N 32°59′41.8″, long: E 130°32′08.8″). This is a medium to coarse grained granite. The major minerals of this rock are quartz, plagioclase, alkali feldspar, biotite and muscovite. Plagioclase occurs as euhedral to subhedral crystal and exhibits indistinct albite twin and oscillatory zoning. Undulatory extinction is observed in quartz. Zircon and opaque mineral are common accessory minerals. The registration number is 137671.

Most zircon grains are 150 to 280 μm length with prismatic and elongation ratio from 1.8 to 4.2. CL images are relatively bright with distinct oscillatory zoning. 35 spots from 27 grains were analyzed and 34 data are concordant. The weighted mean age of all concordant data indicates 106.0 ± 1.0 Ma (1 datum rejected; MSWD = 1.6).

Discussion

Because of the high closure temperature of the decay system and the robust nature of zircon, U–Pb age is commonly interpreted to indicate the plutonic age of granitoids. In Chikuhi area, the zircon U–Pb ages of samples in this study and an age previously reported (Miyazaki *et al.*, 2018) are well-concentrated in a narrow range from 106.6 to 105.5 Ma. There is no relationship between zircon U–Pb ages and the classification of "older" or "younger" granitoids. It is thought that the plutonism in the Chikuhi area was concentrated in ca. 106 Ma. The WR Rb–Sr ages previously reported by Osanai *et al.* (1993) of the study area are 121.3 ± 8.4 and 116.8 ± 12.7 Ma. Present zircon U–Pb ages are in a range of their high 2σ data errors.

Zircon U–Pb ages of granitoids in the Higo belt, southern part of the central Kyushu, concentrated in

Table 2. Summaries of localities and weighted mean ages of each sample.

sample name	registration No.[1)]	locality	rock body	n of data			Age	MSWD
				All	Conc.	Calc.		
KKC1	137666	N33°03′32.0″E130°52′29.0″	Kikuchi granite	42	41	40	106.6 ± 0.9	1.7
KKC2	137668	N33°03′32.0″E130°47′29.3″	Kikuchi granite	39	38	35	105.7 ± 1.2	2.4
TMN1	137667	N33°02′05.4″E130°50′51.0″	Tamana granodiorite	59	56	52	105.7 ± 0.7	1.2
TMN2	137670	N32°58′40.9″E130°38′30.3″	Tamana granodiorite	46	43	37	105.5 ± 0.9	1.3
TGT1	137671	N32°59′41.8″E130°32′08.8″	Tsutsugatake granite	35	34	33	106.0 ± 1.0	1.6

Age errors are 95% conf.; Conc.: concordant, Calc.: used for age calculation.

1) The number of rock specimen in the collection database of the National Museum of Nature and Science (http://db.kahaku.go.jp/webmuseum_en/).

113–108 Ma (Nagata and Otoh, 2021 and references therein). In contrast, zircon U–Pb ages of northern Kyushu, northern than Matsuyama-Imari Tectonic line, mainly range from 105–98 Ma (Adachi *et al.*, 2012; Yuhara *et al.*, 2019; Miyazaki *et al.*, 2018). Granitoids in the Chikuhi area indicate zircon U–Pb ages of ca. 106 Ma which is intermediate between Higo belt and northern Kyushu areas. The trend in zircon age data is more noticeable than in WR data, i.e. Cretaceous granitoid in Kyushu roughly becomes younger northward.

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