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CHIME ages of monazite from the Shinshiro Tonalite of the Ryoke belt in the Mikawa area, Aichi Prefecture

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ABSTRACT

The Shinshiro Tonalite located on the north of the Median Tectonic Line in the Mikawa area is the oldest pluton among the post-tectonic intrusive in the eastern Ryoke belt. monazites recovered fron three samples of the leucocratic varieties of the Shinshiro Tonalite yiled CHIME ages of 86.0±4.7, 85.2±3.3 and 85.5±5.5 Ma. These ages, interpreted as the time of the emplacement, are some 15 Ma younger than the CHIME monazite ages for the Ryoke gniess, and slightly older than the CHIME monazite ages for the subsequent Mitsuhashi Granodiorite (ca. 84 Ma).

INTRODUCTION

Recent CHIME monazite geochronology revealed that the Ryoke gneiss in the Mikawa area attained to the metamorphic grade of monazite formation (lower amphibolite facies) at ca. 100 Ma (Suzuki et al, 1994a,b). The Ryoke gneiss underwent subsequently the peak metamorphism and the emplacement of granitic rocks. Identification of granitic plutons and their intrusive order had been established in early 1970's on the basis of the field relations, petrographic features and morphology of accessory zircon (e.g. Sakai et al., 1960; Ryoke Research Group, 1972). The oldest intrusive in the Mikawa area is the Kamihara Tonalite which is followed successively by the Tenryukyo Granodiorite, Kiyosaki Granodiorite, Shinshiro Tonalite, Mitsuhashi Granodiorite, Inagawa Granodiorite and Busetsu Granite. Unlike the KamiharaTonalite, Tenryukyo Granodiorite and Kiyosaki Granodiorite, the Shinshiro Tonalite forms a discordant pluton with a contact aureole (Asami and Hoshino, 1980). This indicates the Shinshiro Tonalite to be a post-tectonic intrusive. Its emplacement age, therefor, may provide a constraint on the duration of the Ryoke metamorphism. Previous K-Ar dating of the Shinshiro Tonalite yielded 73.3±2.9 Ma hornblende age and 68.0±2.1 Ma biotite age (Uchiumi et al., 1990). These ages, however, are not considered to represent the emplacement time, because they are younger than the subsequent Mitsuhashi Granodiorite (ca. 84 Ma CHIME monazite ages, Suzuki et al., 1994a,b) and the Busetsu Granite (82.5±3.9 Ma Rb-Sr whole-rock isochron ages, Shibata and Ishihara, 1979; ca. 77 Ma CHIME monazite ages, Suzuki et al.,1994a). To know the

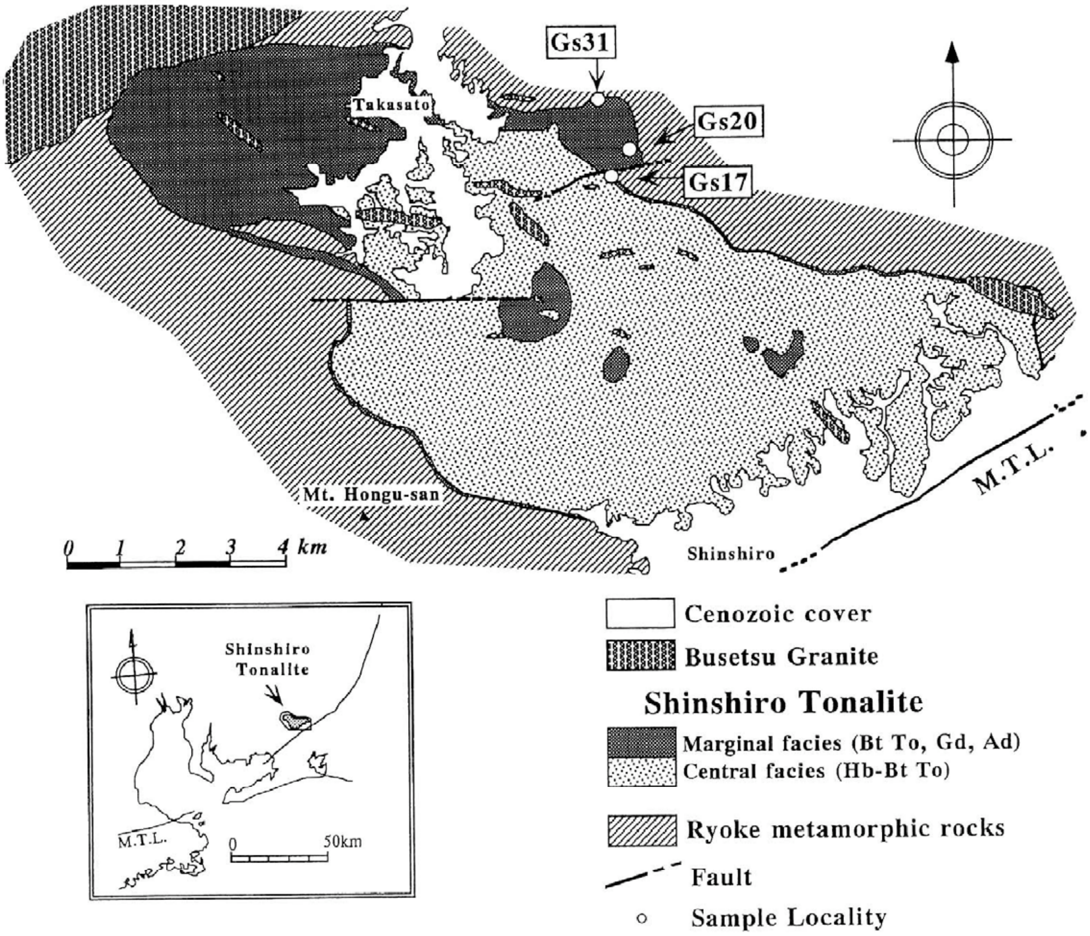

Fig. 1. Geological map of the Shinshiro Tonalite (after Ohtomo, 1985). Sample localities are also shown. Note that the Busetsu Granite intruded the Shinshiro Tonalite in many places. To: tonalite, Gd: granodiorite, AD: adamellite, M.T.L.: the Median Tectonic Line.

emplacement age by an alternative method, we have made CHIME age determinations of monazites from the leucocratic varieties of the Shinshiro Tonalite. Although our CHIME geochronological research on the Shinshiro Tonalite is in progress, we here present the dating results and discuss their meaning.

OUTLINE OF THE SHINSHIRO TONALITE

The Shinshiro Tonalite forms a stock-like body with an area of 14 x 6 km on the north of the Median Tectonic Line (Fig. 1). It intruded discordantly in to the Ryoke metamorphic rocks which show a general trend of NE-SW direction and consist mainly of pelitic, psammitic and siliceous gneisses. Asami and Hoshino (1980) divided the gneiss on the western side of the pluton into three mineral zones; andalusite zone, sillimanite zone and sillimanite-orthoclase zone southward. Atsumi (1984) reported a paragenesis of andalusite-sillimanite-muscovite from the northeast of the pluton. The pluton forms a contact aureole of 2 km in width and yields the andalusite-orthoclase assemblage overprinted on the regional assemblages (Asami and Hoshino, 1980). The assemblage of the contact metamorphism is stable on lower pressure conditions than those for the regional assemblage. This suggests that the Shinshiro Tonalite emplaced after a significant uplift of the Ryoke belt. The Shinshiro Tonalite is intruded by the Busetsu Granite (Fig. 1).

The pluton of the Shinshiro Tonalite comprises coarse-grained hornblende-biotite tonalite in the center and biotite tonalite to granite in the margin (Ohmoto, 1985; see Fig. 1). The central tonalite, characterized by the presence of prismatic hornblende of 8-11 mm long, grades into the marginal biotite tonalite, biotite granodiorite and muscovite-bearing biotite granite within a narrow zone of several dozens of meters. Some marginal facies contain garnet as accessory phase.

SAMPLE DESCRIPTION

We examined a number of samples, and found monazite from three samples from the northern margin of the pluton. The sample localities are given in Fig. 1.

Sample Gs17 (137°28'35"E, 34°57'40"N), medium-grained biotite tonalite, was collected from a dike extended from the margin of the pluton at the granite-gneiss boundary. It consistts mainly of quartz (30%), plagioclase (60%), potash feldspar (0.1%) and biotite (9.4%). Plagioclase forms euhedral grains of 6-7 mm in length, and shows marked compositional zoning. Quartz occurs as anhedral grains and as interstitials.

Sample Gs20 (137°28'25"E, 34°57'52"N) was collected from a ca. 15 m thick dike intruding into psammitic gneiss. The sample, medium-grained garnet-bearing two-mica adamellite, consists mainly of quartz (39%), plagioclase (24%), potash feldspar (23%), biotite (7.9%) and muscovite (4.7%). Potash feldspar, more than 1 cm in size, shows a poikilitic texture and includes euhedral grains of plagioclase, biotite and muscovite.

Sample Gs31 (137°28'13"E, 34°58'21"N), medium-grained garnet-bearing biotite tonalite, was collected from the immediate contact with psammitic gneiss. It consists of quartz (32%), plagioclase (60%), potash feldspar (1.2%), biotite (6.6%), garnet (trace) and muscovite (trace). Plagioclase, ca. 2 mmin size, displays a marked compositional zoning and its calcic center is usually sericitized. Garnet forms euhedral grains of smaller than 1 mmin diameter.

All samples contain monazite, zircon, apatite, pyrrhotite and pyrite as accessories. Monazite grains are yellow-colored and euhedral, and range in size from 0.1 to 0.4 mm. They differ in grain shape and size from monazites in adjacent Ryoke gneiss, which are largely anhedral and smaller than 0.15 mm in size. We consider that monazite grains in the samples crystallized from magmatic melt.

Table 1. Electron microprobe analyses of ThO_2, UO_2 and PbO in monazites from samples of the Shinshiro Tonalite. ThO_2*: sum of the measured ThO_2 and ThO_2 equivalent of the measured UO_2.

No.	Grain No.	ThO_2 wt.%	UO_2 wt.%	PbO wt.%	Age Ma	ThO_2* wt.%
Sample : Gs17						
1	M01-01	6.40	0.110	0.024	82	6.75
2	M01-02	7.68	0.129	0.029	84	8.09
3	M02-01	7.63	0.098	0.028	83	7.95
4	M02-02	8.16	0.116	0.030	83	8.53
5	M03	7.40	0.110	0.027	83	7.75
6	M04-01	8.39	0.170	0.032	84	8.93
7	M04-02	9.01	0.177	0.034	85	9.58
8	M04-03	9.27	0.142	0.035	85	9.72
9	M05-01	7.90	0.165	0.032	89	8.43
10	M05-02	7.42	0.135	0.027	81	7.85
11	M06-01	8.29	0.124	0.031	84	8.68
12	M06-02	6.95	0.115	0.026	83	7.32
13	M07-01	7.54	0.121	0.027	81	7.93
14	M07-02	8.31	0.099	0.031	85	8.63
15	M08-01	7.76	0.077	0.028	83	8.00
16	M08-02	5.48	0.092	0.021	86	5.77
17	M09-01	6.33	0.097	0.023	81	6.64
18	M09-02	8.70	0.126	0.032	83	9.11
19	M09-03	8.14	0.113	0.030	82	8.50
20	M10-01	8.30	0.117	0.031	85	8.68
21	M10-02	8.30	0.138	0.032	85	8.74
22	M11	9.00	0.155	0.034	83	9.49
23	M12-01	7.37	0.060	0.027	86	7.57
24	M12-02	7.53	0.059	0.028	85	7.72
25	M12-03	8.29	0.083	0.031	84	8.56
26	M13-01	7.04	0.105	0.026	82	7.38
27	M13-02	7.03	0.097	0.027	87	7.34
28	M14-01	6.63	0.100	0.025	86	6.95
29	M14-02	7.62	0.132	0.029	86	8.04
30	M15-01	7.93	0.134	0.030	86	8.36
31	M15-02	7.83	0.124	0.029	82	8.22
32	M16-01	8.51	0.136	0.033	86	8.94
33	M16-02	8.26	0.153	0.031	85	8.75
34	M16-03	7.76	0.135	0.029	83	8.19
35	M17-01	7.19	0.088	0.027	86	7.47
36	M17-02	8.16	0.097	0.030	85	8.47
37	M17-03	7.74	0.094	0.029	85	8.04
38	M18-01	7.47	0.128	0.029	86	7.88
39	M18-02	8.03	0.114	0.031	86	8.40
40	M18-03	6.58	0.083	0.025	86	6.84
41	M19-01	8.07	0.069	0.030	86	8.29
42	M19-02	7.94	0.069	0.029	83	8.16
43	M20-01	7.96	0.117	0.030	84	8.33
44	M20-02	6.11	0.110	0.023	84	6.46
45	M20-03	7.14	0.150	0.027	82	7.62
46	M21-01	7.87	0.135	0.031	89	8.30
47	M21-02	6.76	0.099	0.025	85	7.08
48	M21-03	7.27	0.114	0.027	84	7.63
49	M22-01	7.54	0.108	0.029	85	7.88
50	M22-02	9.02	0.138	0.034	86	9.47
51	M22-03	8.33	0.121	0.031	84	8.72
Sample : Gs20						
1	M01-01	6.18	0.254	0.025	83	6.99
2	M01-02	6.02	0.263	0.025	86	6.87
3	M01-03	5.56	0.213	0.024	91	6.24
4	M01-04	5.88	0.241	0.024	86	6.66
5	M01-05	5.75	0.253	0.024	85	6.56
6	M01-06	6.42	0.150	0.025	84	6.90
7	M02-01	6.72	0.369	0.029	86	7.90
8	M02-02	6.69	0.391	0.029	87	7.94
9	M02-03	6.52	0.364	0.027	84	7.68
10	M02-04	6.82	0.375	0.029	85	8.02
11	M03-01	6.99	0.175	0.028	87	7.55
12	M03-02	7.60	0.110	0.029	87	7.95
13	M04-01	6.13	0.252	0.025	85	6.93
14	M04-02	5.45	0.109	0.021	86	5.80
15	M04-03	5.80	0.164	0.023	86	6.32
16	M05-01	8.78	0.227	0.034	84	9.51
17	M05-02	8.12	0.199	0.030	82	8.76
18	M05-03	7.91	0.238	0.032	88	8.67
19	M06-01	4.87	0.634	0.025	84	6.90
20	M06-02	7.90	0.641	0.037	87	9.95
21	M06-03	4.53	0.523	0.022	84	6.21
22	M07-01	6.44	0.370	0.027	84	7.62
23	M07-02	7.62	0.348	0.032	86	8.73
24	M08-01	7.71	0.167	0.030	85	8.24
25	M08-02	6.29	0.200	0.024	82	6.93
26	M08-03	5.57	0.235	0.023	86	6.32
27	M08-04	7.87	0.195	0.031	85	8.49
28	M08-05	7.53	0.209	0.029	83	8.20
29	M09-01	6.76	0.303	0.028	85	7.73
30	M09-02	7.32	0.201	0.029	86	7.97
31	M09-03	6.30	0.342	0.027	86	7.40
32	M09-04	6.94	0.282	0.029	87	7.85
33	M10-01	2.42	0.551	0.016	89	4.18
34	M10-02	2.46	0.556	0.015	81	4.24
35	M11-01	6.18	0.112	0.024	87	6.54
36	M11-02	6.94	0.145	0.026	82	7.40
37	M12-01	9.84	0.379	0.040	86	11.1
38	M12-02	7.56	0.408	0.031	83	8.87
39	M12-03	8.96	0.372	0.036	84	10.2
40	M12-04	6.74	0.334	0.028	85	7.81
41	M13	6.28	0.238	0.025	85	8.04
42	M14-01	8.16	0.293	0.033	85	9.09
43	M14-02	7.84	0.291	0.032	86	8.77
44	M14-03	8.33	0.181	0.033	87	8.91
Sample : Gs31						
1	M01-01	3.94	0.073	0.015	82	4.18
2	M01-02	5.49	0.087	0.021	86	5.77
3	M02-01	4.50	0.101	0.018	86	4.82
4	M02-02	6.25	0.149	0.024	83	6.72
5	M03-01	5.71	0.352	0.025	86	6.84
6	M03-02	5.78	0.350	0.025	85	6.90
7	M03-03	4.87	0.114	0.019	84	5.23
8	M04-01	7.68	0.114	0.029	86	8.05
9	M04-02	7.59	0.115	0.029	86	7.95
10	M04-03	7.32	0.126	0.028	84	7.72
11	M04-04	7.96	0.132	0.029	82	8.39
12	M04-05	7.86	0.136	0.030	85	8.30
13	M04-06	7.60	0.133	0.030	87	8.03
14	M05-01	7.12	0.181	0.027	82	7.70
15	M05-02	6.85	0.170	0.028	90	7.40
16	M06-01	6.76	0.136	0.026	86	7.20
17	M06-02	5.02	0.554	0.024	82	6.80
18	M07-01	4.41	0.090	0.018	88	4.70
19	M07-02	4.84	0.068	0.018	82	5.05
20	M08-01	6.82	0.091	0.025	83	7.11
21	M08-02	7.30	0..082	0.027	85	7.56
22	M08-03	5.43	0.700	0.021	86	5.65

RESULTS

Crushing of samples, separation of monazite, preparation of polished thin sections were done through the method described by Suzuki and Adachi (1991a,b). Monazite were analyzed on a JEOL JXA-733 electron microprobe equipped with three wavelength dispersive-type spectrometers. Intensities of ThMα, UMβ and PbMα lines only were measured. The background was measured at two optimum positions on both sides of each line peak position. The X-ray intensities for both the line peak and two backgrounds were integrated for 300s. The measurement was repeated three times, and the arithmetic average was taken. After the correction of intensity data with an

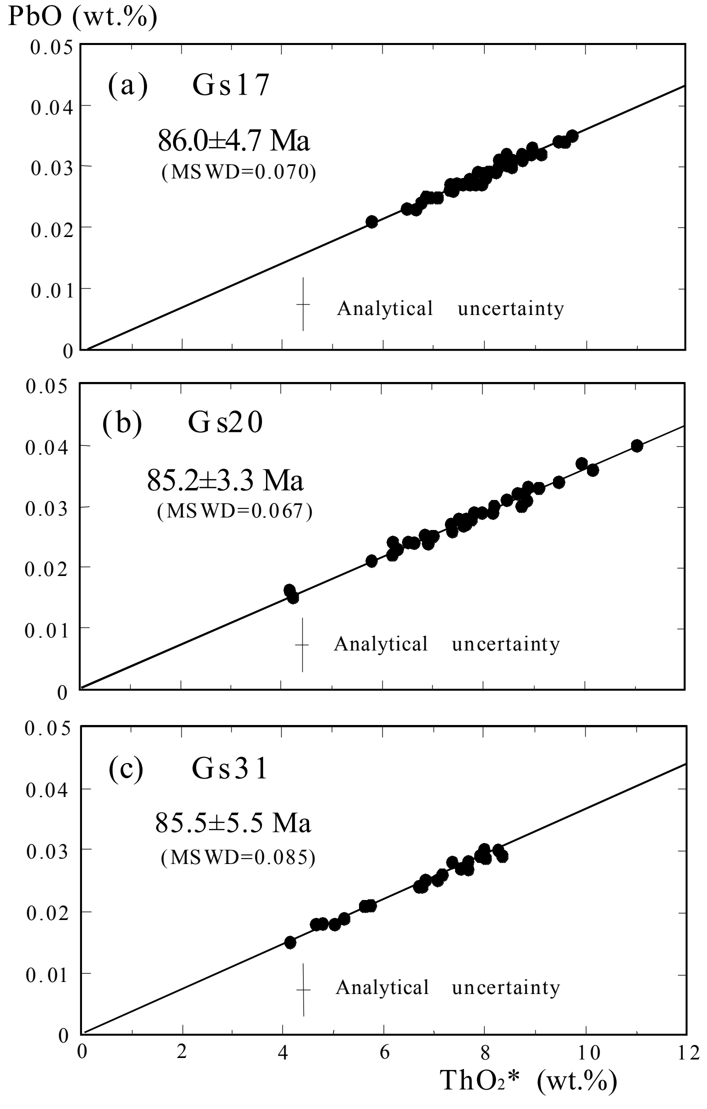

Fig. 2. PbO-ThO$_2$* plots for monazite from sample Gs17 (a), sample Gs20 (b) and sample Gs31 (c). Error bars in the figures represent 2σ analytical uncertainty, and errors given to the ages are of 2σ.

average composition of monazite, the CHIME ages were calculated through the method proposed by Suzuki and Adachi (1991a,b).

The microprobe analyses of ThO_2, UO_2 and PbO together with apparent age and ThO_2* are listed in Table 1. Plots of PbO vs. ThO_2* are given in Figs. 2a, 2b and 2c. A total of 51 analyses on 22 monazite grains from sample Gs17 are regressed with an isochron of 86.0±4.7 Ma (Fig. 2a). monazite grains from sample Gs20 show a wide compositional variation; the ThO_2* content ranges from 5.8 to 11.1 %. A total of 44 analyses on 14 grains yield a well-defined isochron of 85.2±3.3 Ma (Fig. 2b). Monazite grains from sample Gs31 are low in the ThO_2* content than those from the rest samples. The 22 data points for 8 grains can be combined with an isochron of 85.5±5.5 Ma (Fig. 2c). The CHIME monazite ages for the three samples coincide well with one another. Since the blocking temperature of Pb-diffusion in monazite (650-700°C) is close to solidus temperatures of granitic magmas (Suzuki et al., 1994a), we consider the ca. 86 Ma CHIME ages as the time for the emplacement of the Shinshiro Tonalite.

CONCLUDING REMARKS

The present CHIME monazite ages are placed in the context of the field evidence in the Mikawa area (Fig. 3), together with the previously reported CHIME ages for the Ryoke gneiss and granitoids (Suzuki et al., 1994a,b) in the area. Our CHIME age data are in accord with the field relations.

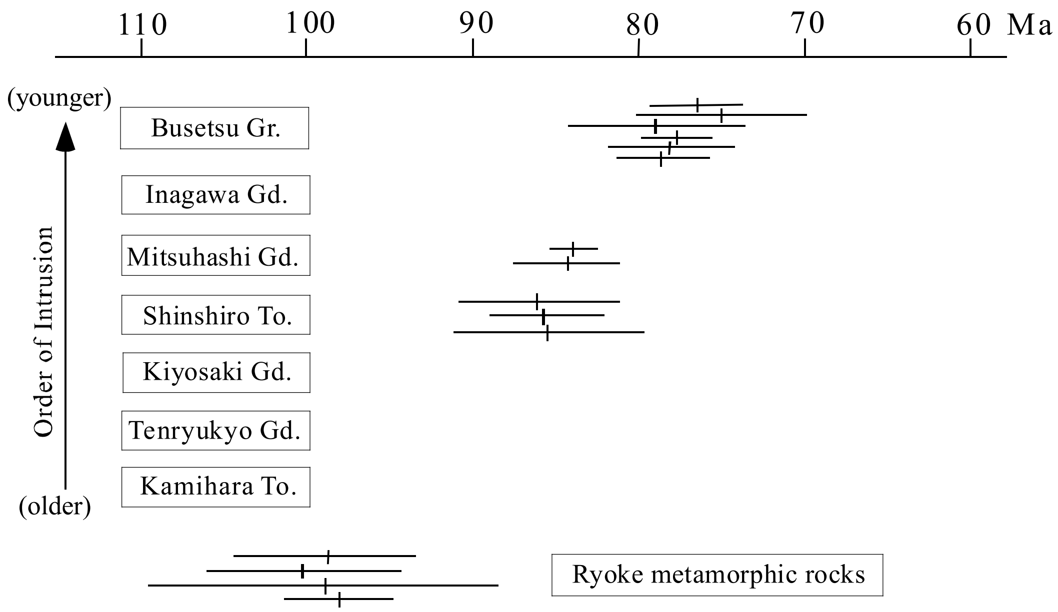

Fig. 3 Summary of CHIME monazite ages obtained in this study and those reported by Suzuki et al. (1994a,b). CHIME age data are in harmony with the order of intrusion.

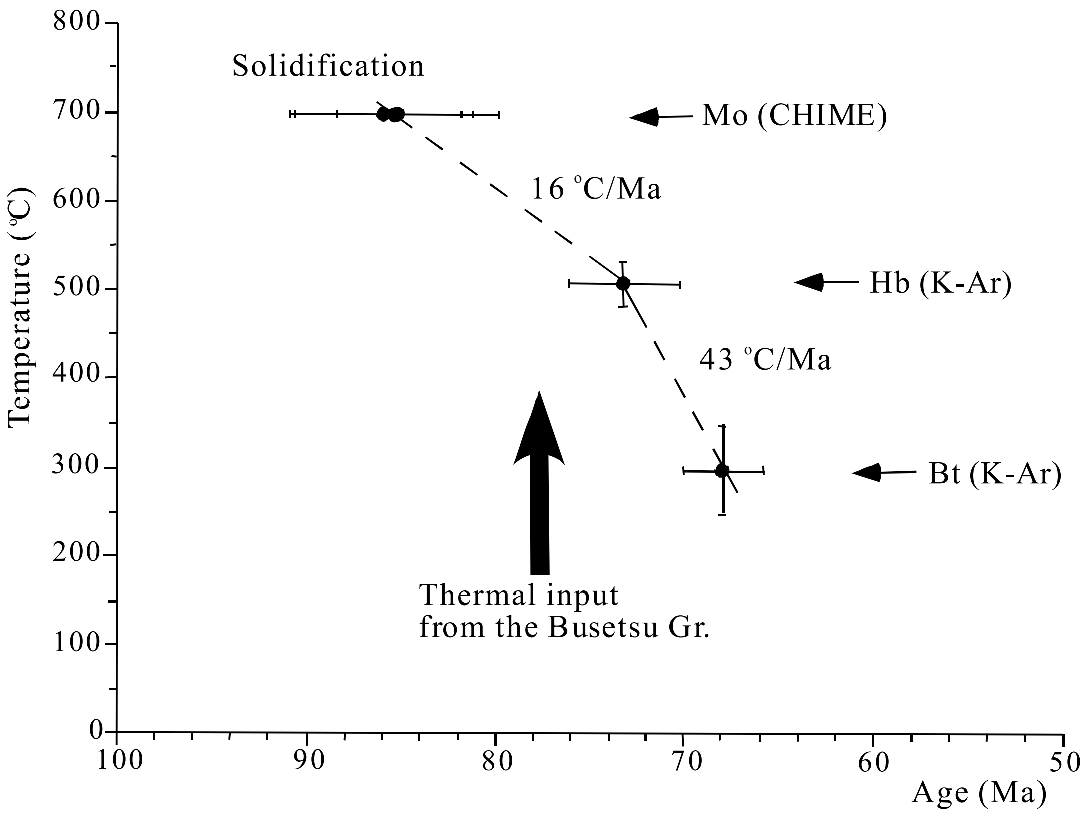

Fig. 4. Cooling history for the Shinshiro Tonalite from the solidification (700℃) to the closure temperature for biotite in K-Ar system (300℃). Average cooling rates are also shown. The emplacement age for the Busetsu Granite is based on its CHIME monazite ages (Suzuki et al., 1994b).

The CHIME ages of monazite from the Ryoke gneiss are ca. 100 Ma (Suzuki et al., 1994a,b). Smith and Barreiro (1990) found that monazite formed at the lower amphibolite facies conditions records the time since the formation even with subsequent excursions into the upper amphibolite facies. Following this observation, Suzuki et al. (1994a) considered the ca. 100 Ma monazite ages as the time of the first attainment to the lower amphibolite facies during the progressive stage of the Ryoke metamorphism. Since the Shinshiro Tonalite emplaced after a significant uplift of the Ryoke belt, about 15 Ma is the maximum estimate for the duration of the peak metamorphism.

The mineral ages of the Shinshiro Tonalite were dated by the K-Ar method (Uchiumi et al., 1990); they are 73.3±2.9 Ma for hornblende and 68.0±2.1 Ma for biotite. The closure temperatures of these minerals are estimated to be 510±25 and 300±50°C, respectively (Dodson and McClelland-Brown, 1985). If we assume the temperature for the emplacement (monazite crystallizaion) to be 700°C, we can obtain average cooling rates of 16°C/Ma for the temperature range between 700 and 510℃ and 43°C/Ma for the range between 510 and 300°C (Fig. 4). This cooling curve can be hardly explained by a simple conductive cooling. Alternatively, we consider that the Shinshiro Tonalite was reheated above the closure temperature for hornblende by the emplacement of the Busetsu Granite at ca. 77 Ma ago. In this case, the area appears to have cooled at a rate of about 40℃/Ma after the thermal input. This high cooling rate may be owing to the regional uplift and cooling of the Ryoke belt before the emplacement of the Busetsu Granite.

The K-Ar and Rb-Sr biotite ages for the Ryoke gneiss and granitic rocks in the Mikawa area concentrate at around 68 Ma (see the complication of Suzuki et al., 1994b). These ages have been interpreted as the time of the regional uplift (e.g. Suzuki et al., 1994b). The present study, however, revealed that the area had undergone a significant uplift before the emplacement of the Shinshiro Tonalite at ca. 86 Ma age. The ca. 68 Ma K-Ar biotite ages should be interpreted as the time of cooling to the closure temperature of biotite after the regional reheating caused by the emplacement of the Busetsu Granite.

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