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CHIME monazite ages of the Otagiri and Ichida Granites in the Komagane area, Nagano Prefecture

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ABSTRACT

The Otagiri Granite comprises peraluminous fine-grained two-mica granites to granodiorites, and intrudes into the Ichida Granite within the eastern part of the Ryoke metamorphic belt. Monazites from three samples of the Otagiri Granite and a sample of the Ichida Granite were dated by the Chemical Th-U-total Pb Isochron Method (CHIME). The ages are 77.4±3.1 Ma, 76.3±2.8 Ma and 77.2±3.5 Ma for the Otagiri Granite and 79.4±3.1 Ma for the Ichida Granite. The CHIME monazite ages, interpreted as the time of the emplacement, agree with the intrusive relation. The present dating shows that the 100–90 Ma Rb-Sr whole-rock isochron ages (Yuhara, 1994) for the Otagiri Granite is fortuitous. The CHIME monazite ages support the previous correlation of the Otagiri Granite with the Kadoshima and Busetsu Granites of ca. 77 Ma age (Kagami, 1972; Shibata and Ishihara, 1979; Nakai et al., 1985; Suzuki et al., 1994b).

INTRODUCTION

Peraluminous fine-grained two-mica granites to granodiorites occur in discontinuous plutons over an area of a hundred kilometer long, from Komagane to Mikawa within the eastern Ryoke metamorphic belt (e.g. Ryoke Research Group, 1972). They are named as the Otagiri Granite in the Komagane area, the Kadoshima Granite in the Kadoshima area and the Busetsu Granite in the Mikawa area. Rocks of individual plutons, despite the wide range in spatial distribution, are petrographically quite similar; the fine-grained texture and the presence of muscovite, garnet, monazite, xenotime, sillimanite and/or cordierite are the diagnostic features of the Otagiri, Kadoshima and Busetsu Granites from other granitoids in the eastern Ryoke belt. All plutons of the Otagiri, Kadoshima and Busetsu Granites intrude into the Inagawa Granodiorite which is a continuous pluton extended from Komagane to Mikawa and is regarded as the representative of the Younger Ryoke Granite (i.e. post-tectonic granites, Ryoke Research Group, 1972). The intrusive relations coupled with the petrographic similarity lead many scholars to a conclusion that the Otagiri, Kadoshima and Busetsu Granites formed simultaneously. The Kadoshima Granite has been dated by the Rb-Sr whole-rock isochron method to be 76.1 Ma (Kagami, 1973; originally 73.3 Ma, 6 data were recalculated using the currently accepted decay constant of 1.42×10^{-11}/y). The Busetsu Granite shows Rb-Sr whole-rock isochron ages of $82.5 \pm 3.9(1\sigma)$ Ma (Shibata and Ishihara, 1979) and 75.4 ± 10.4 Ma (Nakai et al., 1985; originally 71.7 ± 1.4 Ma, it was recalculated by discarding data for metabasite and hornblende gabbro) and CHIME monazite ages of $75.0 \pm 5.1 - 78.9 \pm 5.3$ Ma (Suzuki et al., 1994b).

The Otagiri Granite was recently dated by Yuhara (1994) by the Rb-Sr whole-rock isochron method. The ages are 71.6 ± 6.8, 99.0 ± 10.9 and 92.7 ± 13.8 Ma. These dates, at least 99.0 Ma one, are surprisingly older than those for the Kadoshima and Busetsu Granites. If this is true, the previous correlation of the Otagiri Granite with the Kadoshima and Busetsu Granites is invalid. However, the Rb-Sr ages of the Otagiri Granite appear to be inconclusive, since the Rb-Sr isotopic data exhibit a significantly large scatter. To check the existence of the ca. 90−100 Ma plutons by an alternative method, we have determined CHIME (chemical Th-U-total Pb isochron method) monazites ages using an electron microprobe for samples of the Otagiri Granite. Also dated is the Ichida Granite which is intruded by the 92.7 ± 13.8 Ma pluton of the Otagiri Granite. The monazite age can be regarded as representing the time for crystallization of granitic intrusives, since the blocking temperature for Pb in monazite (ca. 700°C; Parrish, 1990; Smith and Barreiro, 1990; Suzuki et al., 1994a) is close to the temperature for crystallization of granitic magmas (e.g. Merril et al., 1970; Robertson and Wyllie, 1971).

GEOLOGY AND EXPERIMENTS

The Komagane area, situated in the northeastern part of the Ryoke belt, is underlain mainly by the Ryoke metamorphic rocks, a series of granitoids and Quaternary covers (Fig. 1, Murayama and Katada, 1957). The Ryoke metamorphic rocks consist mainly of pelitic and psammitic schists and gneisses. The metamorphic grade increases from the biotite zone in the northwest of the mapped area to the sillimanite-cordierite-orthoclase zone in the southeast (Ono, 1969).

Five granitic intrusives are distinguished in the area, the Inagawa Granodiorite (coarse-grained porphyritic granodiorite to adamellite), the Ichida Granite (medium-grained biotite granodiorite to adamellite), the Otagiri Granite (mainly two-mica adamellite), the Kisokoma Granodiorite (medium-grained hornblende-biotite granodiorite) and the unnamed biotite granodiorite at Miyata. The intrusive sequence of these granitoids (Fig. 2) was synthesized on the basis of field evidence and petrographic correlations by Ryoke Research Group (1972). The relation between the Otagiri Granite and Ichida Granite is not shown in the original context given by Ryoke Research Group, but Yuhara (1994) found that the former intrudes into the latter at the Nakatagiri River. Although the geologic relation between the Otagiri Granite and Kisokoma Granodiorite is never detectable, the Kisokoma Granodiorite is considered to intrude after the emplacement of the Otagiri Granite from the mode of occurrence (Tsuchiya, 1966).

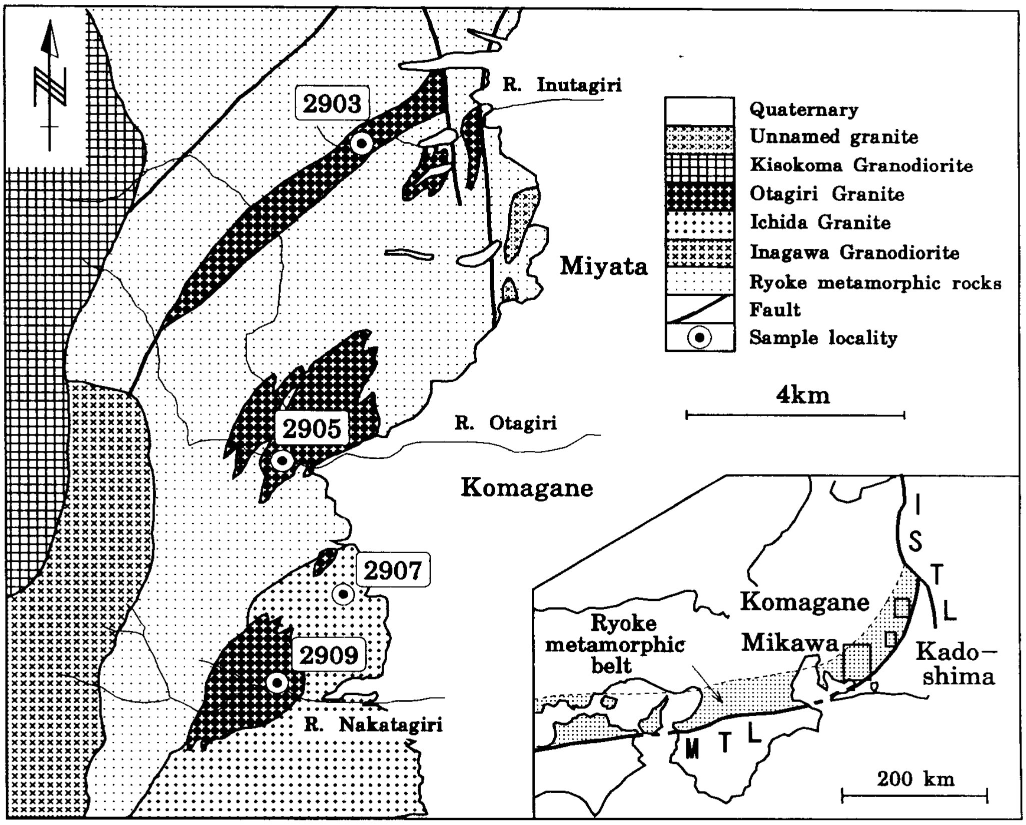

Fig. 1. Geologic map of the Komagane area showing sample localities of granitoids (simplified from Murayama and Katada, 1957).

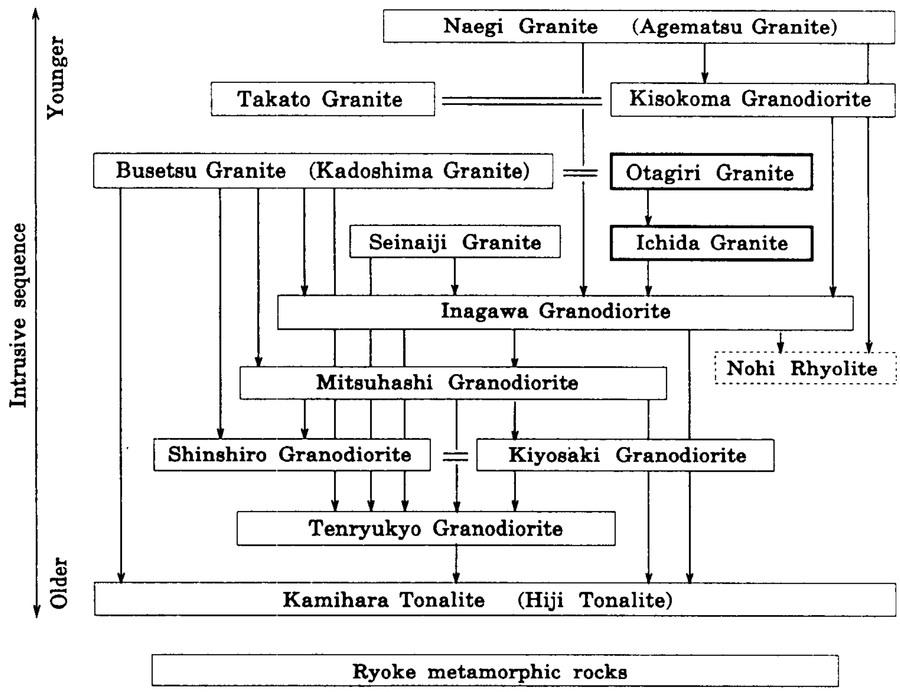

Fig. 2. Intrusive relations of granitoids in the eastern Ryoke metamorphic belt (simplified and modified from Ryoke Research Group, 1972).

Table 1. Microprobe analyses of ThO_2, UO_2 and PbO of monazites from the Otagiri Granite (samples 2903, 2905 and 2909) and the Ichida Granite (sample 2907) in the Komagane area. ThO_2*: sum of the measured ThO_2 and ThO_2 equivalent of the measured UO_2.

Grain No.	ThO_2 wt.%	UO_2 wt.%	PbO wt.%	Age Ma	ThO_2* wt.%
Sample 2903: Otagiri Granite					
M01-01	10.9	0.287	0.038	77	11.8
M01-02	6.86	0.163	0.024	76	7.38
M01-03	10.7	0.261	0.038	79	11.5
M01-04	10.8	0.338	0.040	80	11.9
M02	6.34	0.168	0.023	79	6.88
M03-01	6.82	0.227	0.024	76	7.55
M03-02	7.47	0.225	0.026	74	8.19
M03-03	6.42	0.211	0.023	76	7.09
M03-04	7.98	0.221	0.029	78	8.69
M04-01	8.61	0.305	0.032	79	9.59
M04-02	9.22	0.171	0.031	75	9.77
M04-03	9.06	0.247	0.034	81	9.85
M05-01	5.51	0.285	0.021	77	6.42
M05-02	5.29	0.267	0.020	76	6.15
M05-03	6.10	0.396	0.026	83	7.37
M06-01	9.16	0.237	0.032	76	9.92
M06-02	7.81	0.173	0.026	74	8.36
M06-03	8.13	0.331	0.033	84	9.19
M07-01	4.62	0.147	0.018	82	5.09
M07-02	7.64	0.203	0.028	79	8.29
M08	7.90	0.208	0.028	78	8.56
M09-01	7.04	0.191	0.026	79	7.65
M09-02	7.60	0.169	0.026	76	8.14
M10-01	7.07	0.305	0.027	80	8.05
M10-02	8.52	0.325	0.030	73	9.56
M11-01	5.99	0.129	0.022	80	6.40
M11-02	9.38	0.301	0.034	78	10.3
M11-03	9.65	0.360	0.036	78	10.8
M12-01	5.68	0.225	0.021	79	6.40
M12-02	4.34	0.163	0.017	81	4.86
M13-01	9.25	0.228	0.033	77	9.98
M13-02	6.93	0.229	0.026	80	7.66
M14-01	8.31	0.149	0.029	77	8.79
M14-02	9.20	0.165	0.033	79	9.73
M14-03	8.42	0.082	0.030	80	8.68
M14-04	8.08	0.099	0.027	77	8.40
M14-05	8.16	0.137	0.029	78	8.60
M15-01	4.68	0.207	0.018	80	5.34
M15-02	4.70	0.137	0.017	77	5.14
M15-03	3.35	0.044	0.012	81	3.49
M15-04	6.23	0.235	0.022	76	6.98
M15-05	6.50	0.091	0.023	79	6.79
M16-01	7.89	0.215	0.027	74	8.58
M16-02	7.49	0.218	0.027	76	8.19
M16-03	8.94	0.335	0.035	81	10.0
M16-04	10.1	0.375	0.037	78	11.3
M16-05	5.88	0.146	0.020	74	6.35
M17-01	8.60	0.283	0.032	79	9.51
M17-02	7.20	0.148	0.024	74	7.67
M17-03	9.68	0.165	0.032	73	10.2
M17-04	11.0	0.345	0.040	78	12.1
M17-05	10.4	0.347	0.038	77	11.5
M18-01	9.01	0.213	0.031	76	9.69
M18-02	8.28	0.197	0.031	81	8.91
M18-03	9.00	0.275	0.034	82	9.88
M18-04	7.40	0.268	0.026	75	8.26
M18-05	7.87	0.182	0.025	71	8.45
M19-01	10.7	0.280	0.038	78	11.6
M19-02	10.1	0.197	0.034	74	10.7
M19-03	8.73	0.199	0.033	82	9.37
M19-04	6.93	0.107	0.023	73	7.27
M19-05	7.87	0.208	0.027	75	8.54
M19-06	10.9	0.240	0.038	78	11.7
M19-07	10.7	0.212	0.036	75	11.4
M19-08	10.8	0.299	0.037	74	11.8
M19-09	11.3	0.273	0.042	81	12.2
M19-10	6.96	0.140	0.024	76	7.41
Sample 2905: Otagiri Granite					
M01-01	8.09	0.641	0.034	79	10.1
M01-02	6.90	0.325	0.024	72	7.94
M01-03	9.13	0.213	0.032	78	9.81
M01-04	7.69	0.361	0.031	82	8.85
M01-05	7.71	0.463	0.027	70	9.19
M02-01	10.6	0.223	0.037	77	11.3
M02-02	10.3	0.209	0.036	77	11.0
M02-03	10.1	0.150	0.034	76	10.6
M02-04	9.71	0.138	0.031	73	10.2
M02-05	9.97	0.166	0.032	72	10.5
M02-06	9.14	0.120	0.030	75	9.53
M03-01	4.79	0.050	0.016	77	4.95

Table 1. (continued).

Grain No.	ThO_2 wt.%	UO_2 wt.%	PbO wt.%	Age Ma	ThO_2* wt.%
M03-02	5.74	0.096	0.020	77	6.05
M03-03	5.70	0.075	0.019	76	5.94
M04-01	4.92	0.092	0.017	75	5.21
M04-02	5.40	0.106	0.019	78	5.74
M04-03	5.59	0.047	0.019	78	5.74
M04-04	5.57	0.045	0.020	83	5.71
M04-05	5.05	0.029	0.015	69	5.14
M05-01	6.62	0.696	0.030	81	8.85
M05-02	6.01	0.290	0.023	77	6.94
M05-03	4.58	0.371	0.020	82	5.77
M05-04	6.28	0.357	0.024	77	7.42
M06-01	6.64	0.135	0.023	77	7.07
M06-02	5.38	0.084	0.019	81	5.65
M06-03	6.31	0.122	0.021	73	6.70
M06-04	6.58	0.117	0.023	78	6.96
M06-05	10.3	0.282	0.035	74	11.2
M07-01	5.26	0.087	0.019	82	5.54
M07-02	5.19	0.096	0.018	76	5.50
M07-03	4.56	0.098	0.016	76	4.87
M07-04	4.80	0.099	0.016	73	5.12
M07-05	4.36	0.062	0.015	78	4.56
M07-06	4.94	0.091	0.017	75	5.23
M08-01	9.21	0.095	0.033	82	9.52
M08-02	9.07	0.129	0.030	75	9.48
M08-03	9.90	0.087	0.034	78	10.2
M08-04	10.1	0.126	0.033	75	10.5
M08-05	8.53	0.091	0.029	78	8.82
M08-06	6.58	0.121	0.022	74	6.97
M08-07	8.63	0.091	0.028	75	8.92
M08-08	9.90	0.111	0.032	73	10.3
M08-09	9.75	0.112	0.034	79	10.1
M09-01	3.59	0.060	0.012	75	3.78
M09-02	4.91	0.078	0.017	78	5.16
M09-03	5.18	0.094	0.019	83	5.48
M09-04	5.04	0.072	0.018	81	5.27
M09-05	5.27	0.074	0.017	73	5.51
M10-01	7.98	1.75	0.047	82	13.6
M10-02	9.18	2.08	0.052	78	15.8
M10-03	8.98	2.15	0.051	77	15.9
M10-04	8.75	2.04	0.047	73	15.3
M10-05	8.74	2.37	0.054	79	16.3
M11-01	5.63	0.113	0.019	75	5.99
M11-02	5.62	0.091	0.018	72	5.91
M11-03	5.71	0.107	0.020	76	6.05
M11-04	5.73	0.154	0.021	78	6.22
M11-05	5.35	0.097	0.018	74	5.66
Sample 2909: Otagiri Granite					
M01-01	3.44	0.918	0.020	74	6.38
M01-02	4.98	0.739	0.024	78	7.35
M01-03	3.88	1.03	0.024	79	7.18
M02-01	5.78	0.195	0.020	75	6.41
M02-02	5.90	0.249	0.019	68	6.70
M02-03	6.57	0.087	0.023	79	6.85
M03-01	4.29	0.057	0.013	71	4.47
M03-02	3.71	0.044	0.013	78	3.85
M04-01	4.65	0.077	0.018	87	4.90
M04-02	4.91	0.111	0.016	72	5.26
M04-03	5.00	0.075	0.016	73	5.24
M04-04	5.17	0.053	0.018	78	5.34
M05-01	6.99	0.121	0.024	77	7.38
M05-02	7.69	0.160	0.029	83	8.20
M05-03	7.70	0.163	0.026	76	8.22
M05-04	7.02	0.169	0.024	75	7.56
M05-05	7.26	0.186	0.025	75	7.85
M06-01	6.63	0.135	0.024	82	7.06
M06-02	6.39	0.124	0.023	81	6.79
M06-03	6.13	0.100	0.019	70	6.45
M06-04	6.03	0.069	0.022	82	6.25
M06-05	5.78	0.086	0.019	75	6.05
M07-01	7.74	0.118	0.028	82	8.12
M07-02	7.95	0.179	0.028	78	8.52
M07-03	8.91	0.165	0.031	78	9.44
M07-04	8.69	0.164	0.030	78	9.21
M07-05	7.43	0.149	0.026	77	7.91
M08-01	5.82	0.141	0.020	76	6.27
M08-02	7.21	0.172	0.026	80	7.76
M08-03	5.74	0.150	0.020	75	6.22
M08-04	6.29	0.142	0.021	72	6.74
M09-01	3.03	0.187	0.012	78	3.63
M10-01	7.87	0.220	0.027	73	8.57
M10-02	7.56	0.225	0.027	77	8.28

Table 1. (continued).

Grain No.	ThO_2 wt.%	UO_2 wt.%	PbO wt.%	Age Ma	ThO_2* wt.%
M10-03	7.73	0.281	0.027	74	8.63
M10-04	7.56	0.238	0.025	71	8.32
M10-05	7.81	0.217	0.030	84	8.50
M10-06	7.69	0.234	0.027	75	8.44
M11-01	7.32	0.340	0.026	74	8.41
M11-02	6.73	0.371	0.026	78	7.92
M12-01	6.64	0.115	0.023	76	7.01
M12-02	6.64	0.122	0.022	75	7.03
M12-03	5.03	0.048	0.017	75	5.18
M13-01	7.56	0.379	0.029	77	8.77
M13-02	7.76	0.478	0.031	78	9.29
M13-03	7.61	0.430	0.030	79	8.99
M13-04	6.42	0.407	0.025	75	7.72
M13-05	7.38	0.321	0.027	75	8.41
M13-06	7.77	0.425	0.029	74	9.13
M13-07	7.74	0.491	0.031	78	9.31
M13-08	7.33	0.384	0.030	83	8.56
M13-09	7.34	0.430	0.029	79	8.72
M14-01	4.22	0.214	0.015	71	4.91
M14-02	2.46	0.214	0.010	75	3.14
M14-03	3.10	0.245	0.013	81	3.88
M15-01	10.2	0.215	0.034	75	10.9
M15-02	10.2	0.118	0.034	77	10.6
M15-03	9.95	0.137	0.032	73	10.4
M15-04	9.34	0.164	0.033	78	9.86
M15-05	10.4	0.191	0.034	73	11.0
M15-06	10.2	0.181	0.035	77	10.8

Grain No.	ThO_2 wt.%	UO_2 wt.%	PbO wt.%	Age Ma	ThO_2* wt.%
Sample 2907: Ichida Granite					
M01-01	6.07	0.122	0.022	79	6.46
M01-02	5.48	0.130	0.020	80	5.90
M02	4.48	0.124	0.017	80	4.88
M03	5.96	0.126	0.022	80	6.36
M04	3.41	0.143	0.013	80	3.87
M05	5.47	0.143	0.021	84	5.93
M06-01	7.80	0.102	0.026	76	8.13
M06-02	7.89	0.137	0.028	79	8.33
M07-02	6.97	0.129	0.024	78	7.38
M07-02	7.54	0.127	0.027	80	7.95
M08-01	5.84	0.065	0.020	78	6.05
M08-02	6.15	0.093	0.020	74	6.45
M09	2.36	0.127	0.010	85	2.77
M10	3.74	0.097	0.013	78	4.05
M11	3.30	0.032	0.010	69	3.40
M11-02	5.08	0.108	0.018	78	5.43
M12-01	5.86	0.466	0.025	81	7.35
M12-02	6.46	0.194	0.023	76	7.08
M13	3.05	0.109	0.011	76	3.40
M14	3.66	0.043	0.013	81	3.80
M15-01	6.33	0.205	0.022	74	6.99
M15-02	7.91	0.205	0.029	79	8.57
M15-03	8.01	0.166	0.028	77	8.54
M15-04	7.54	0.169	0.027	79	8.08
M15-05	8.20	0.361	0.031	79	9.35
M16	5.34	0.066	0.020	84	5.55
M17	4.10	0.070	0.014	75	4.32
M18-01	5.12	0.062	0.017	74	5.32
M18-02	6.25	0.147	0.023	79	6.72
M19-01	4.98	0.089	0.018	81	5.26
M19-02	4.93	0.076	0.018	83	5.17
M20-01	3.26	0.050	0.011	73	3.42
M20-02	3.75	0.059	0.013	78	3.94
M21-01	4.35	0.072	0.015	75	4.58
M21-02	3.49	0.061	0.013	85	3.68
M22	3.97	0.072	0.013	75	4.20
M23-01	5.17	0.130	0.019	79	5.59
M23-02	4.44	0.095	0.016	80	4.74
M24	5.04	0.078	0.017	76	5.29

The Otagiri Granite forms three plutons at the Inutagiri, Otagiri and Nakatagiri Rivers (Fig. 1). We temporarily call these plutons as the northern, central and southern plutons, respectively. The northern pluton consists entirely of fine-grained two-mica adamellite. The central body comprises fine-grained gray-colored biotite granodiorite, fine-grained two-mica adamellite and fine- to medium-grained leucocratic two-mica granite. Murayama and Katada (1957) found that fine-grained gray-colored biotite granodiorite is intruded by both two-mica varieties with a sharp boundary, and that fine- to medium-grained leucocratic two-mica granite grades abruptly or intrudes with a sharp boundary into fine-grained two-mica adamellite; the central pluton formed through multiple magmatic events. The southern pluton consists of fine-grained two-mica adamellite and fine-grained to coarse-grained leucocratic two-mica granite. Again this pluton possibly formed through multiple magmatic events.

We collected three samples (sample Nos. 2903, 2905 and 2909) of the Otagiri Granite and a sample (sample No. 2907) of the Ichida Granite (Fig. 1). Monazite was analyzed on an electron microprobe (JCXA-733) by the method described by Suzuki et al. (1991), Suzuki and Adachi (1991) and Adachi and Suzuki (1992). The Th, U and Pb analytical results are listed in Table 1; the detection limit of PbO at 2σ confidence level is 0.01 wt.%, and the relative error in the PbO determination is about 15–25 % for 0.02 wt.% of the concentration. Error in CHIME age is given at 2σ level.

CHIME MONAZITE AGES

Otagiri Granite

Sample 2903 from the northern pluton is weakly foliated fine-grained two-mica adamellite, and consists mainly of quartz, K-feldspar, plagioclase, biotite and muscovite. The partial XRF analysis of this sample is listed in Table 2. The normative composition is 31.8 % quartz, 28.6 % orthoclase, 31.8 % plagioclase, 2.2 % corundum and 4.1 % hypersthene. The molar $Al_2O_3/(CaO+Na_2O+K_2O)$ (A/CNK; hereafter) value is 1.15, and the molar $K_2O/(Na_2O+K_2O)$ (K/NK; hereafter) value is 0.52. Plagioclase is zoned with a calcic core and a sodic rim; the calcic core is highly sericitized. Accessories include garnet, apatite, monazite, xenotime, zircon and ilmenite. Titanite is absent, but secondary grains develop in chloritized biotite. Monazite forms euhedral to subhedral crystals and is 0.12 to 0.22 mm long; exceptionally it attains to 0.30 mm. The length/width ratio is in the range between 1.1 and 2.8 and concentrates around 2.1. Monazite contains 3.34–11.3 wt.% ThO_2 and 0.09–0.38 wt.% UO_2. A total of 67 analyses on 19 monazite grains are arrayed linearly on the PbO-ThO_2^* diagram (Fig. 3A), and yield an isochron of 77.4±3.1 Ma (MSWD=0.18).

Sample 2905 from the central pluton is massive fine-grained gray-colored biotite granodiorite, and consists of quartz, plagioclase, K-feldspar and biotite. The A/CNK and K/NK values are 1.14 and 0.41, respectively (Table 2). Compared with other samples from the Otagiri Granite, this is enriched in Zn and Ba but poor in Y and Nb. Primary muscovite is rare, but secondary one

Table 2. Partial XRF analyses of granotoids from the Otagiri and Ichida Granites in the eastern Ryoke Belt.

Sample No.	Otagiri Granite Northern pluton 2903	Otagiri Granite Central pluton 2905	Otagiri Granite Southern pluton 2909	Ichida Granite 2907
SiO_2 (%)	72.6	71.1	71.8	72.7
TiO_2	0.230	0.362	0.259	0.216
Al_2O_3	14.7	15.2	15.1	14.3
FeO*	1.74	2.36	1.91	1.74
MnO	0.044	0.055	0.046	0.040
MgO	0.50	0.67	0.54	0.52
CaO	1.47	2.14	1.65	1.33
Na_2O	2.99	3.33	2.93	2.43
K_2O	4.84	3.48	5.01	5.53
P_2O_5	0.118	0.177	0.126	0.112
Total	99.232	98.874	99.371	98.918
A/CNK	1.15	1.14	1.14	1.15
K/NK	0.52	0.41	0.53	0.60
Cr (ppm)	5.8	14.6	9.0	5.6
Co	2.5	0.6	1.4	1.1
Ni	5.1	4.6	3.6	5.2
Zn	41.2	70.3	48.6	38.4
Rb	157	88.6	200	128
Sr	174	362	191	252
Y	15.7	11.5	16.8	9.1
Zr	132	150	142	115
Nb	15.5	11.6	16.5	11.4
Ba	625	1080	723	1390

FeO*: total Fe as FeO, A/CNK: molar $Al_2O_3/(CaO+Na_2O+K_2O)$ ratio and K/NK: molar $K_2O/(Na_2O+K_2O)$ ratio

develops in the altered core of plagioclase. Accessories are apatite, monazite, zircon, xenotime and ilmenite. Garnet cannot be seen in this sample. Most monazite grains occur in euhedral form of 0.11 to 0.17 mm in length. The length/width ratio rarely attains 1.8. Monazite grains from this sample, unlike those from sample 2903, show high variation in the UO_2 content; the UO_2 content ranges from 0.06 to 2.36 %. The ThO_2 content is in the range between 3.59 and 10.6 %. Figure 3B shows PbO vs. THO_2* plots of 58 analyses on 11 grains. All data points are regressed with a single isochron of 76.3 ± 2.8 Ma (MSWD = 0.20).

Sample 2909 from the southern pluton is weakly foliated fine-grained two-mica adamellite, consisting mainly of quartz, plagioclase, K-feldspar, biotite

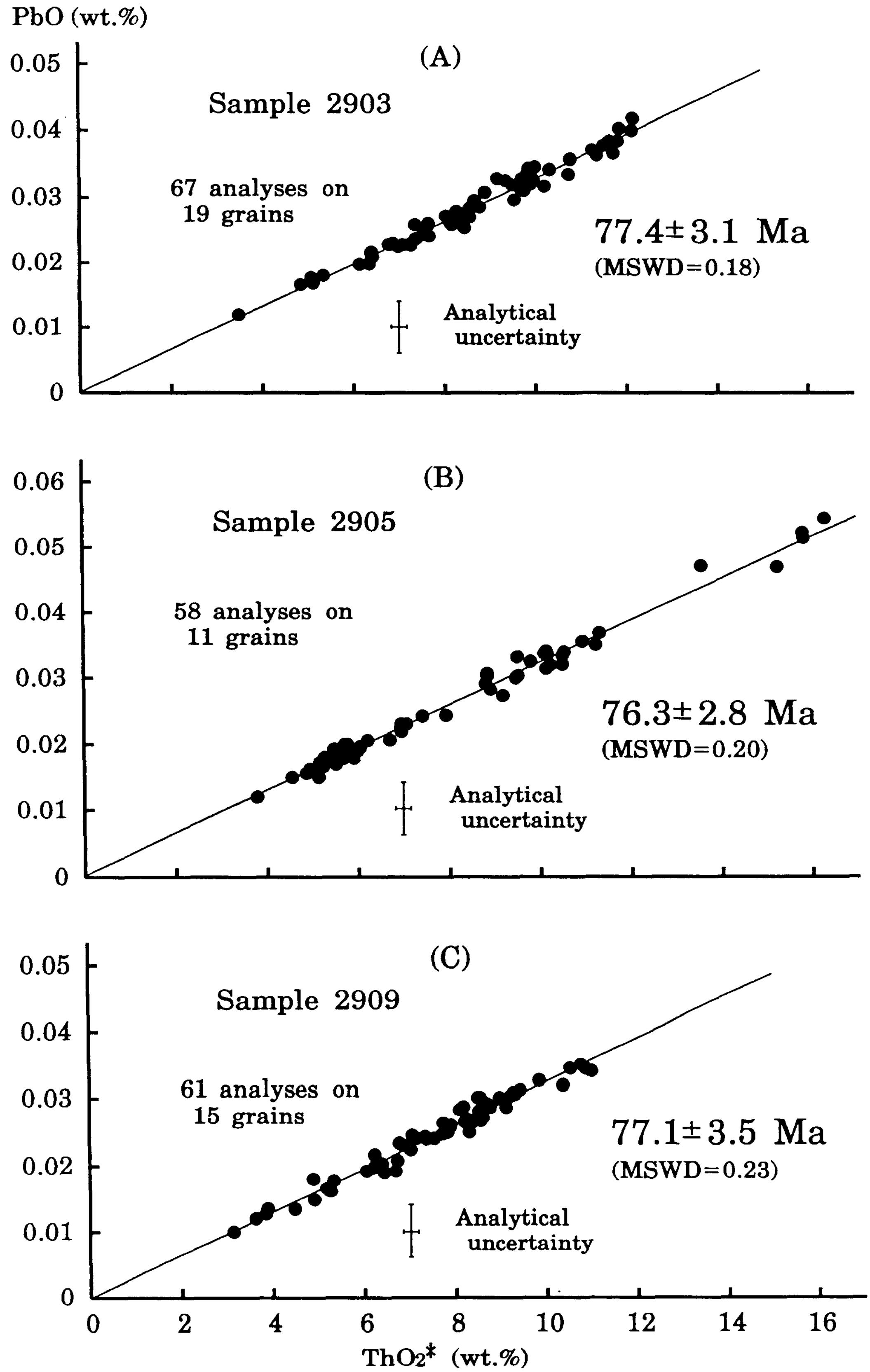

Fig. 3. Plots of PbO vs. ThO_2* of monazites from the northern (A), central (B) and southern plutons of the Otagiri Granite. Error bars in the figure represent 2σ analytical uncertainty, and error given to the age is of 2σ.

and muscovite. The analysis, nearly identical with that of sample 2903, suggests sample 2909 to be peraluminous with the A/CNK value of 1.14 and the K/NK value of 0.53 (Table 2). Accessories are garnet, apatite, monazite, zircon, xenotime and ilmenite. Monazite forms euhedral to subhedral prisms of 0.14 to 0.25 mm in length. The length/width ratio ranges from 1.2 to 1.9. The ThO_2 content ranges from 2.45 to 10.4 % and the UO_2 content from 0.05 to 1.03 %. A total of 61 analyses on 15 grains (Fig. 3C) yields an isochron of 77.2 ± 3.5 Ma (MSWD = 0.23).

Ichida Granite

Sample 2907 from the Ichida Granite is medium-grained biotite adamellite, and consists mainly of quartz, plagioclase, K-feldspar and biotite. This sample shows the A/CNK value of 1.15 and the K/NK value of 0.60 (Table 2). Accessories include apatite, zircon, ilmenite, allanite and monazite. Monazite ranges from 0.13 to 0.28 mm in length, and exceptionally large one is up to 0.35 mm. The ThO_2 content ranges from 2.36 to 7.91 % and the UO_2 content from 0.05 to 0.47 %. The PbO-ThO_2* plots of 39 analyses on 24 grains (Fig. 4) define an isochron of 79.4 ± 3.1 Ma (MSWD = 0.13).

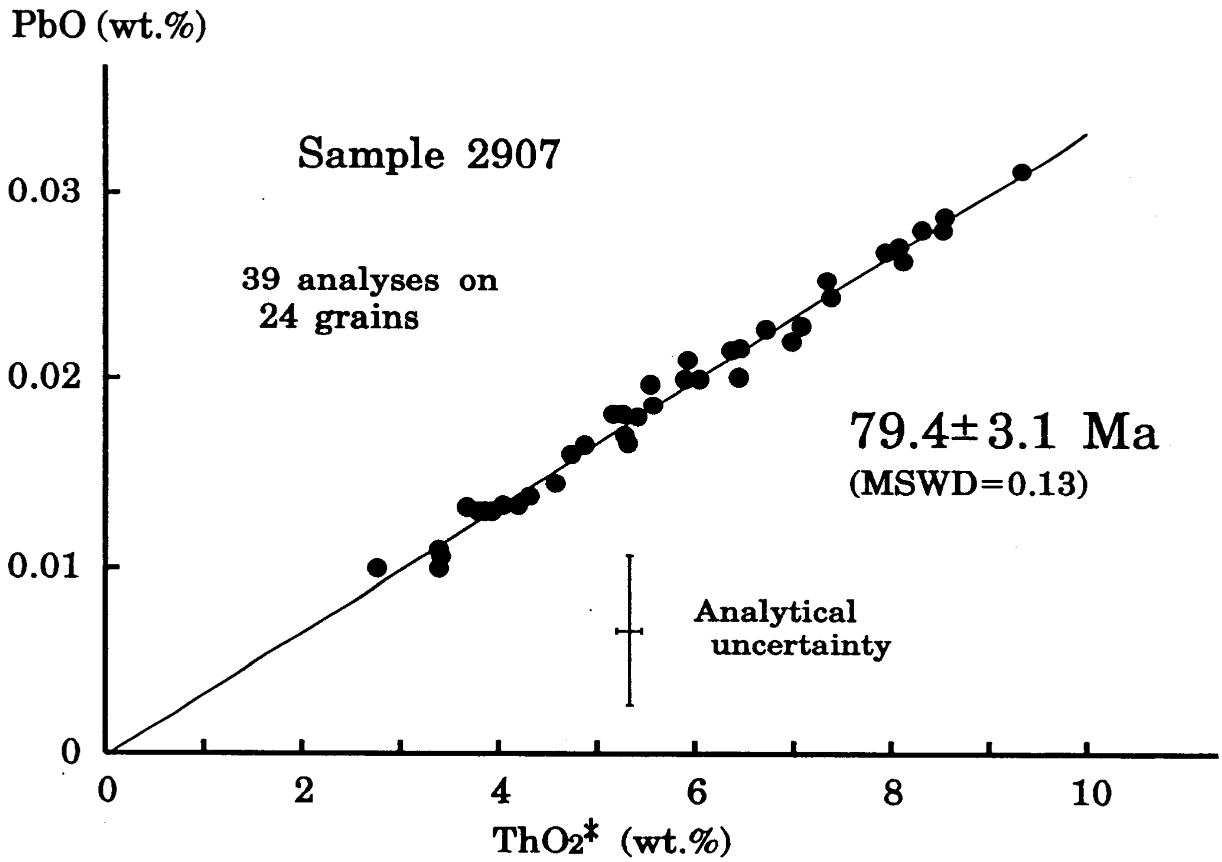

Fig. 4. Plots of PbO vs. ThO_2* of monazites from the Ichida Granite. Explanations for errors are the same as for Fig. 3.

DISCUSSION

The three CHIME monazite ages for the Otagiri Granite are 77.4±3.1 Ma for the northern pluton, 76.3±2.8 Ma for the central pluton and 77.2±3.5 Ma for the southern pluton. The three CHIME dates coincide well with each other within the limit of analytical uncertainty. If we regress all analytical data for three plutons, we obtain an isochron of 77.2±1.7 Ma (MSWD = 0.20) with an intercept value of 0.00003±0.00057.

As mentioned earlier, the Otagiri Granite has been dated by Yuhara (1994) by the Rb-Sr whole-rock isochron method. The Rb-Sr ages are 71.6±6.8, 99.0±10.9 and 92.7±13.8 Ma for the northern, central and southern plutons, respectively (Fig. 5). These Rb-Sr ages, particularly 99.0±10.9 Ma for the central pluton, are inconsistent with the CHIME monazite ages. This inconsistency may not be ascribed to the simple error in both the microprobe and isotopic analyses. Rather, we believe that the 99.0±10.9 Ma Rb-Sr age resulted from isotopic disequilibrium in the Rb-Sr system on the whole-rock scale as documented by Schärer et al. (1984). Inspection of the isochron diagram (Fig. 5) shows a marked scattering of data points for the central pluton (circles). For the age calculation, Yuhara (1994) discarded 6 data (open circles) from 16

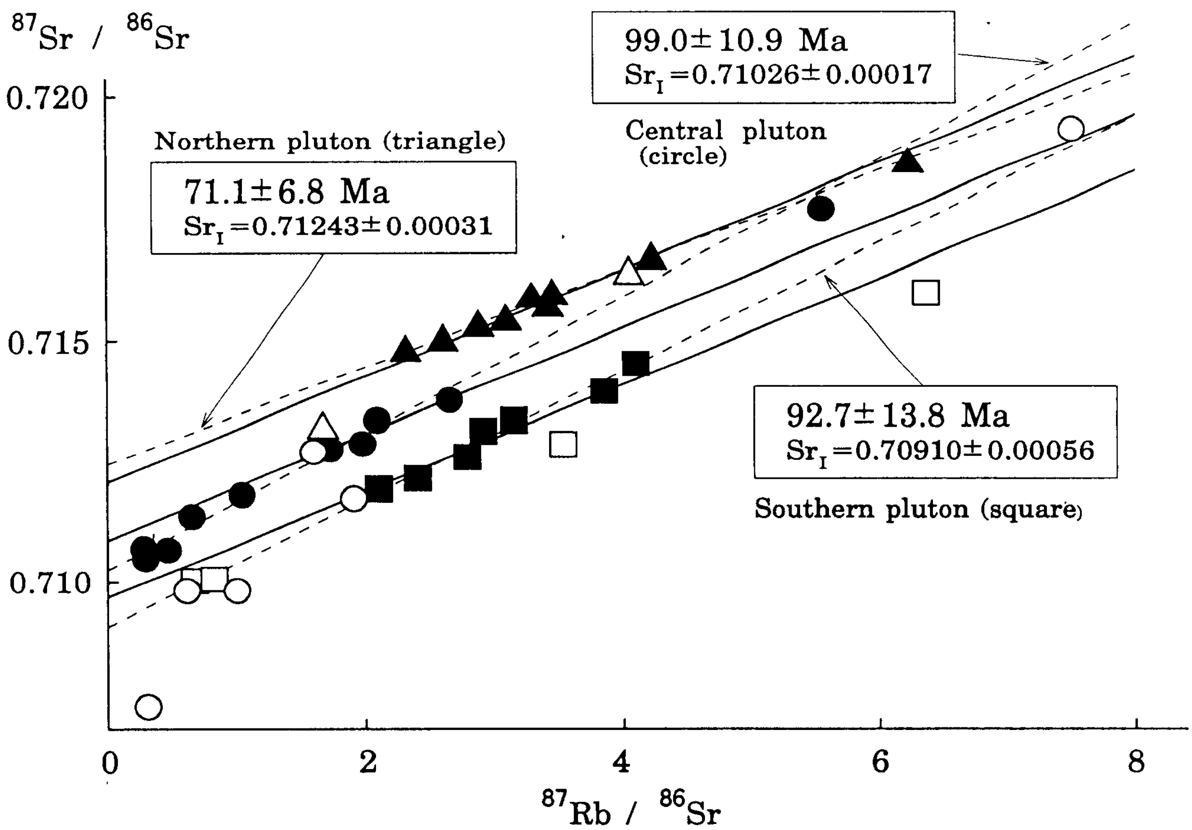

Fig. 5. Rb-Sr isotopic relations in whole-rock samples of the Otagiri Granite (isotopic data from Table 4 of Yuhara, 1994). Solid lines are 77 Ma reference isochrons with different initial $^{87}Sr/^{86}Sr$ ratios, and broken ones represent regression lines of filled data points of individual plutons by Yuhara (1994).

isotopic analyses on the basis of petrographic and chemical criterion. The selected 10 data (solid circles), however, are still not strictly aligned in the isochron diagram; the scatter is beyond analytical uncertainty (mean square of weighted deviated (MSWD) = 3.3). This suggests that the Rb-Sr system is not in equilibrium even in the selected 10 samples. In this connection, it is important to note that the central pluton comprises at least three intrusive units with a clear-cut intrusive relation (Murayama and Katada, 1957). These lines of evidence suggest that the Rb-Sr whole-rock isochron age of 99.0 ± 10.9 Ma might be fortuitous, and not represent the true time of emplacement. This is particularly evident if one examines whole isotopic data of the central pluton with respect to the reference isochron of 77 Ma (solid line); subsets of the data points can be regressed with 77 Ma isochrons of different initial $^{87}Sr/^{86}Sr$ ratios.

The Rb-Sr data for the southern pluton (squares) also are distinctly not aligned in the isochron diagram (Fig. 5), and subsets of them are regressed with 77 Ma isochrons. Again this is a composite pluton (Murayama and Katada, 1957). We consider that the 92.7 ± 13.8 Ma Rb-Sr whole-rock isochron age is fortuitous. The Rb-Sr isochron plots of data for the northern pluton do not show a major effect of the isotopic disequilibrium, and the age of 71.6 ± 6.8 Ma is essentially identical with the CHIME monazite age of 77.4 ± 3.1 Ma. We

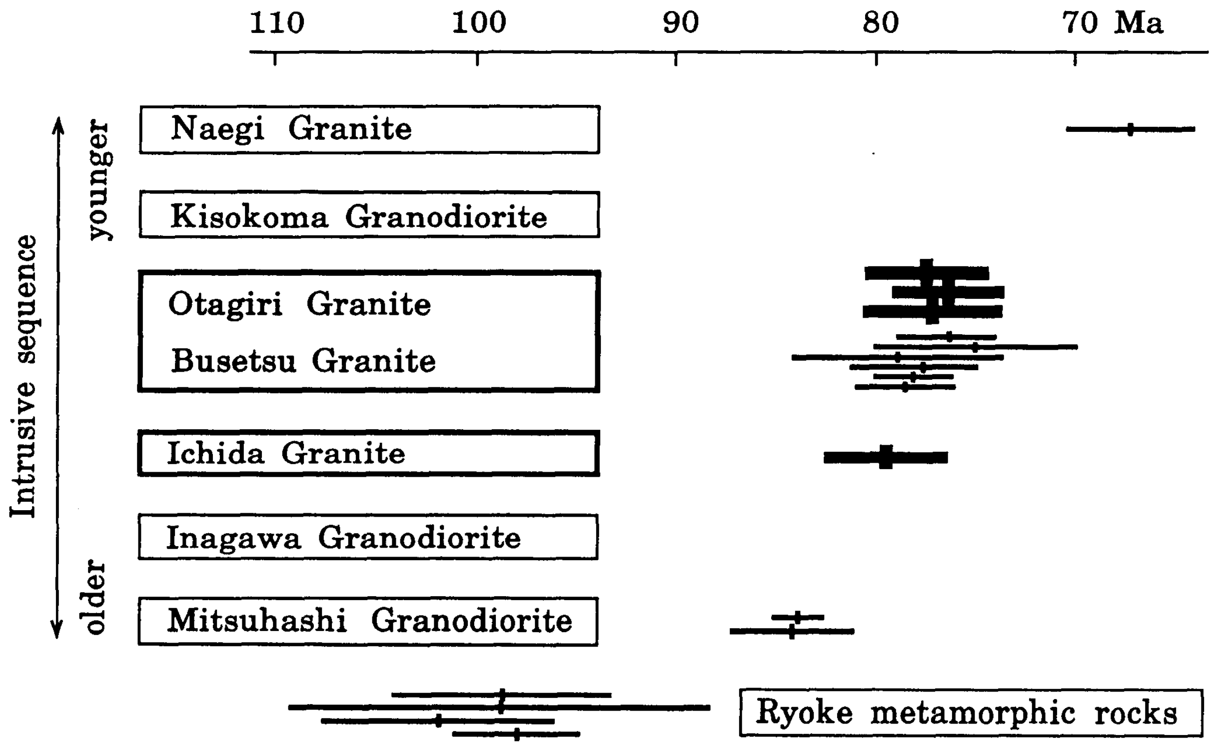

Fig. 6. Diagrammatic presentation of CHIME monazite ages in context of field relations in the Komagane and Mikawa areas. CHIME ages are plotted with error bars (2σ). Bold lines represent age data obtained in this study and other lines represent those reported by Suzuki et al. (1994a,b).

prefer the CHIME monazite ages of ca. 77 Ma (77.4±3.1, 76.3±2.8 and 77.2±3.5 Ma) as representing the time of intrusion and solidification of the northern, central and southern plutons of the Otagiri Granite.

The present CHIME monazite ages of the Otagiri and Ichida Granites are placed in the context of field evidence in the eastern Ryoke belt (Fig. 6), together with the previously reported CHIME monazite ages for gneisses and granitoids (Suzuki et al., 1994a,b). The ca. 77 Ma CHIME ages of the Otagiri Granite just overlap with those of the Busetsu Granite (75.0±5.1 – 78.9±5.3 Ma, Suzuki et al., 1994b), and appear to be slightly younger than the CHIME monazite age of 79.4±3.1 Ma for the Ichida granite; the ages presented herein are in good harmony with the intrusive relation that the Otagiri Granite intrudes into the Ichida Granite. Although we are uncertain whether the Otagiri, Kadoshima and Busetsu Granites are of comagmatic or not, we can state that they were emplaced simultaneously at ca. 77 Ma.

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