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Late Precambrian ages for granitic rocks intruding the Hida Metamorphic Rocks

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Abstract: Rb-Sr whole-rock analyses were carried out on granitic dikes and hornblende gneiss of the Hida Metamorphic Belt at Kagasawa, Hida Mountains. Detailed field observation reveals the intrusion of three types of granitic dikes; coarse-grained granite, medium- and fine-grained granodiorites in order of decreasing age. Well-defined isochron ages were not obtained on these granitic rocks because of the scatter of data points, which reflects the opening of Rb-Sr whole-rock system during later events. Rb-Sr model ages, however, suggest three stages of plutonism at about 1100, 700 and 300 Ma, in accordance with the contact relation. The results clearly indicate that the coarse- and medium-grained granitic rocks, together with hornblende gneiss, originated in late Precambrian time.

Mineral ages of the granitic rocks and hornblende gneiss confirm that all the rocks at Kagasawa were subjected to the major metamorphism at 250-220 Ma, and further affected thermally by the intrusion of the Funatsu Granitic Rocks.

Introduction

During the regional mapping of the Shirokimine district in the Hida Mountain, an interesting outcrop of hornblende gneiss intruded by granitic dikes was noticed on the riverbed of the Miya River at Kagasawa, Toyama Prefecture (NOZAWA *et al.*, 1981). Detailed survey revealed that three different types of granitic rocks are intruded into the hornblende gneiss. As the temporal relationship between the gneiss and granitic rocks is clear, we attempted to date these rocks with a hope of clarifying the plutonic and metamorphic history of the Hida Metamorphic Belt. The results turned out to give a clear evidence for the Precambrian origin for the rocks at Kagasawa. This paper reports the details of the age results and discusses the importance of the Precambrian ages.

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Geological outline and brief description of the outcrop

The Hida Metamorphic Rocks are generally thought to be the oldest metamorphic complex in the Japanese Islands. Their age, however, has been a focus of dispute among Japanese geologists. Although they are closely surrounded by middle Paleozoic formations, probably oldest fossil-bearing formations in Japan, their very contact with the surrounding Paleozoic formations is found nowhere, demarcated by fault or covered by younger formations, otherwise intercalated with granitic intrusives. Their only one age evidence is the unconformable cover of the Jurassic-Cretaceous Tetori Group.

The studied outcrop at Kagasawa (36°26′ 08″N, 137°13′ 16″E), is located in the middle part of the Miyagawa Mass of the Hida Metamorphic Rocks and is geologically included in the Karahoriyama Formation (NOZAWA *et al.*, 1981), composed mostly of

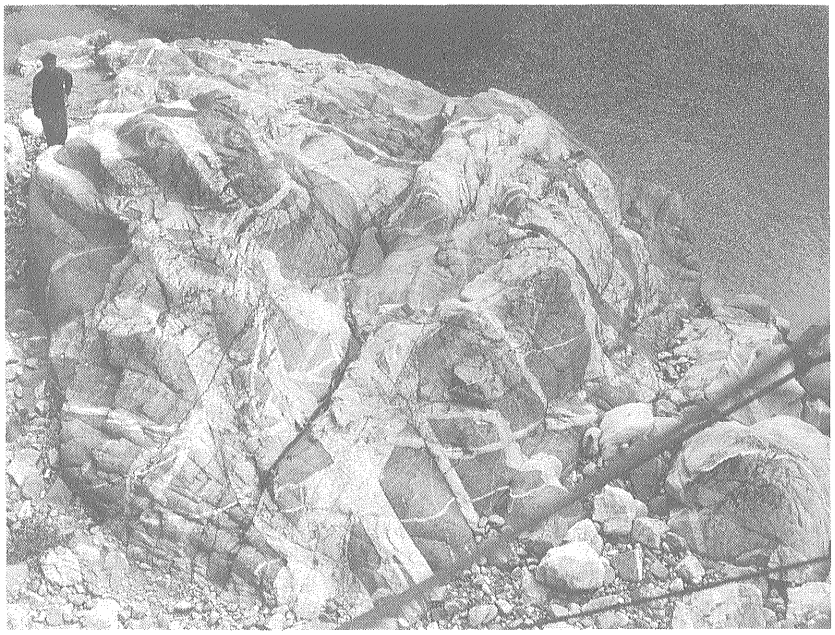

Fig. 1 Outcrop of granitic dikes at Kagasawa, Hida Mountains. The dikes intruding horizontally into the hornblende gneiss (darker part) are of fine-grained granodiorite, whereas those intruding more or less vertically are of coarse-grained granite.

hornblende gneiss and hornblende-biotite gneiss, intercalated with pelitic gneiss and limestone.

Here, on the outcrop, a round-shaped mass of hornblende gneiss, 15×10 m in size, is exposed isolatedly on the riverbed of the Miya River (Fig. 1). The detailed geological map of the mass is shown in Fig. 2. Its relation with the closest country rocks, biotite-hornblende gneiss, is not known as the boundary is covered by Recent river gravel. The mass is slightly different from the country rocks petrographically, with more abundant hornblende and with much weaker foliation, thereby it is supposed that the mass is undoubtedly a member rock of the country rocks but is a heterogeneous part with conformable shape and internal foliation with the country rocks.

The isolated mass is composed mainly of foliated hornblende gneiss with subordinate amount of granitic dikes. The hornblende gneiss is heterogeneous. Its foliation is generally strong in the northern half and is almost obliterated in the southern half. It is irregularly banded in mafic and a little more felsic parts. Its foliation changes in various sense, often with minor fault or slip and sometimes cuts each other just like layered mafic rocks. Under the microscope, its components are nearly uniform, despite its apparent difference by bands. It is composed mainly of common green hornblende, chloritized biotite, plagioclase, quartz and small amount of microcline. Its accessory mineral is sphene, iron ore, apatite and several secondary minerals.

The granitic dikes are intruded into the hornblende gneiss mass in various size and direction. Generally, they are 2-20 cm wide, linear but often irregular in direction and width even in a single dike. They, however, can be divided into three categories after mutual contact relation, together with slight difference of petrography. They are as follows in order of decreasing age.

Coarse-grained granite

It is a light colored, non-foliated, relatively

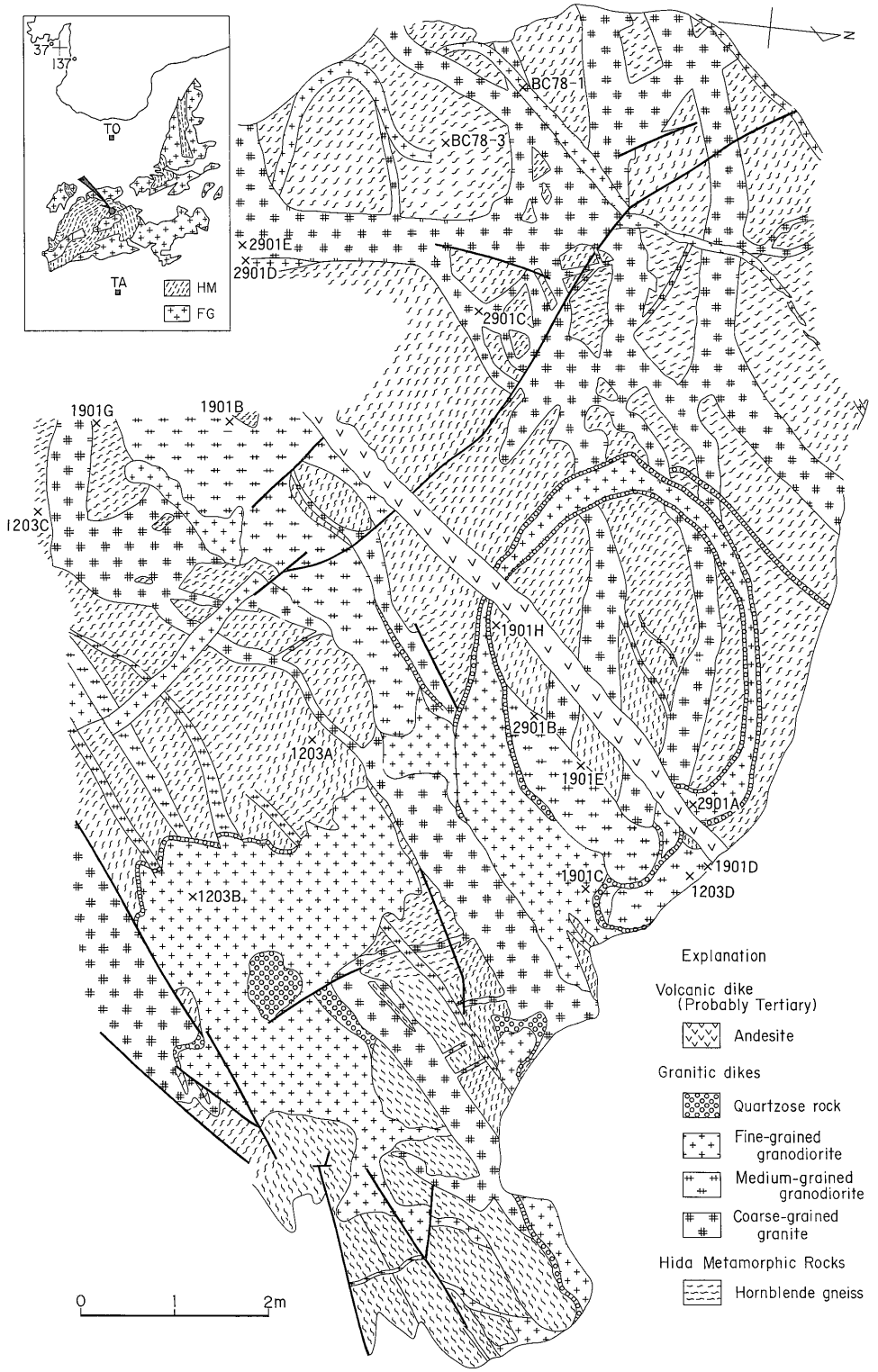

Fig. 2 Geological sketch map of the outcrop at Kagasawa showing sample localities.
HM: Hida Metamorphic Rocks, FG: Funatsu Granitic Rocks, TO: Toyama, TA: Takayama.

coarse-grained granite. It has shape of dike but quite irregular in width and direction of intrusion and is also heterogeneous in petrography. Under the microscope, it is composed mainly of microcline, quartz and plagioclase. A subordinate amount of entirely chloritized biotite and muscovite is contained with a small amount of apatite. Alteration is relatively strong throughout the rock.

Medium-grained granodiorite

It is a light-colored, non-foliated, medium-grained granodiorite, with aplitic appearence. It is usually irregular in shape and relatively small in quantity in comparison with the coarse-grained granite and fine-grained granodiorite. Under the microscope, it is composed mainly of microcline, quartz and plagioclase. Chloritized biotite and muscovite are contained with subordinate amount of sphene, apatite and iron ore. Graphic intergrowth is often found. Fairly strong alteration are found throughout the rock.

Fine-grained granodiorite

A part of it has a relatively regular direction of intrusion: nearly horizontal, and others are irregular in shape. Most of them are fringed by quartzose rim, some part of which develops independently in a irregular shape. It is light-colored, fine-grained, relatively uniform granodiorite with aplitic appearence. Under the microscope, it is composed mainly of biotite, plagioclase, quartz and microcline with a small amount of apatite and zircon which gives heavy halo to biotite in contact. Biotite is partly chloritized but mostly remains fairly fresh with grass-brown tint. Small amount of apatite is contained and iron ores are not found. Graphic intergrowth is seldom found. It suffers from weak alteration especially on plagioclase.

Samples for age determination were taken from various parts of the outcrop. Localities of the samples; 5 samples from hornblende gneiss, 2, 5 and 5 samples from coarse-, medium-, and fine-grained granitic rocks, respectively, are given in Fig. 2. The locality of two samples (2902A, 2902B) is about 10 m east of the outcrop and not shown in Fig. 2.

Analytical methods

Whole-rock samples were prepared from 1–4 kg of rock, and minerals were seperated by an isodynamic separator and heavy liquid. All plagioclase samples contain some amount of quartz. Rb and Sr concentrations of samples were determined by isotope dilution method except for a few samples that were analyzed by X-ray fluorescence method. Isotope dilution and $^{87}Sr/^{86}Sr$ ratio analyses for whole-rock samples were carried out by a

Table 1 Rb–Sr analytical data for whole-rock samples of granitic and metamorphic rocks at Kagasawa.

Sample No.	Rb* (ppm)	Sr* (ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$
Coarse-grained granite				
2901C	77.31	517.1	0.4330	0.71082
2901E	76.46	447.6	0.4947	0.71203
	77.28	446.6	0.5011	0.71211
2902A	75.20	518.2	0.4202	0.71058
Medium-grained granodiorite				
1203D	163.8	175.1	2.708	0.73214
	163.4	177.8	2.661	
2901B	157.3	185.6	2.453	0.72660
1901B	171	228	2.17	0.72225
1901D	155	202	2.22	0.72963
1901E	161.5	143.3	3.264	0.73253
Fing-grained granodiorite				
1203B	75.88	345.8	0.6363	0.70776
2901A	76.78	323.0	0.6884	0.70833
2901D	76.21	351.0	0.6287	0.70875
1901C	80.54	292.4	0.7976	0.70820
BC78-1	85.6	312	0.794	0.70909
Hornblende gneiss				
1203A	32.36	538.5	0.1740	0.70720
1203C	65.52	687.6	0.2759	0.70784
1901G	77.1	684	0.326	0.70824
1901H	45.11	548.3	0.2383	0.70786
				0.70783
2902B	57.8	476	0.352	0.70836
				0.70824
BC78-3	39.7	741	0.155	0.70779

* 4-digit value by isotope dilution,
3-digit value by X-ray fluorescence.

Table 2 Rb-Sr analytical data for minerals in rocks at Kagasawa.

Sample No.	Mineral	Rb (ppm)	Sr (ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$
1203B	Biotite	504.0	13.75	106.1	0.98327*
	K-feldspar	117.2	397.0	0.8550	0.70825*
	Plagioclase+quartz	9.594	282.0	0.0985	0.70635*
1203D	Biotite	141.1	22.42	18.23	0.7525
	K-feldspar-1	201.3 202.9	217.8 220.1	2.676 2.670	0.7317, 0.7329 0.7321
	K-feldspar-2	251.8	240.3	3.034	0.7333
	Plagioclase+quartz	24.70	72.14	0.9915	0.7277
2901B	K-feldspar	235.2	243.5	2.799	0.7283, 0.7283
	Plagioclase+quartz	22.39	96.17	0.6743	0.7230
2901E	K-feldspar	202.9	548.7	1.071	0.7139
	Plagioclase+quartz	15.42	394.1	0.1133	0.7114

* measured on Isomass 54E

VG Isomass 54E mass spectrometer, whereas most of minerals were analyzed by a JEOL-05RB mass spectrometer. All $^{87}Sr/^{86}Sr$ ratios were normalized to $^{86}Sr/^{88}Sr$ ratio=0.1194, and further adjusted to a value of $^{87}Sr/^{86}Sr$=0.70800 for the E and A standard. Replicate analyses of this standard gave an average $^{87}Sr/^{86}Sr$ ratio of $0.70805 \pm 0.00002(1\sigma)$. Uncertainty in $^{87}Rb/^{86}Sr$ ratio was estimated to be 2%, and that in $^{87}Sr/^{86}Sr$ ratio to be 0.015% and 0.15% for the VG and JEOL mass spectrometers, respectively. Isochron ages were calculated by the least-square method of YORK (1966), and error in Rb-Sr age was given on 2σ level.

The K-Ar analytical method was essentially the same as described in SHIBATA and NOZAWA (1978). Error in K-Ar age was given on 1σ level. Decay constants used in age calculation are: $^{87}Rb\lambda=1.42\times10^{-11}$/y, $^{40}K\lambda_\beta=4.962\times10^{-10}$/y, $^{40}K\lambda_e=0.581\times10^{-10}$/y, $^{40}K/K=0.01167$ atom%.

Results

The Rb-Sr analytical results for whole-rock and mineral samples are given in Tables 1 and 2, respectively, and are plotted on an isochron diagram (Fig. 3), in which the data points for four rock types and minerals are shown by different marks. Because of the scatter of points much exceeding the experimental error and also of the relatively limited Rb/Sr ratio for each of rock types, it is difficult to make a well-difined isochron.

Coarse-grained granite

The coarse-grained granite has too narrow range of Rb/Sr ratio to construct an isochron, hence, the age of the rocks is estimated by assuming an initial ratio as 0.704, which is close to the bulk earth ratio in the late Precambrian. The model ages thus calculated range between 1090 and 1130 Ma; they are lowered to 760-850 Ma if a higher ratio of 0.706 is taken. This granite is the oldest of the three types of granitic rocks, intruding the hornblende gneiss and intruded by both medium- and fine-grained granodiorites. Presumably the Rb-Sr system of this rock was not much disturbed by a later metamorphism, and the age of about 1100 Ma may represent the time of emplacement.

Medium-grained granodiorite

The data points for the medium-grained granodiorite are widely scattered and no isochron can be constructed. However, the points show that this rock type is also considerably old in origin. The model ages assuming an initial ratio of 0.704 range between 590 and 810 Ma with an average of 680 Ma. The

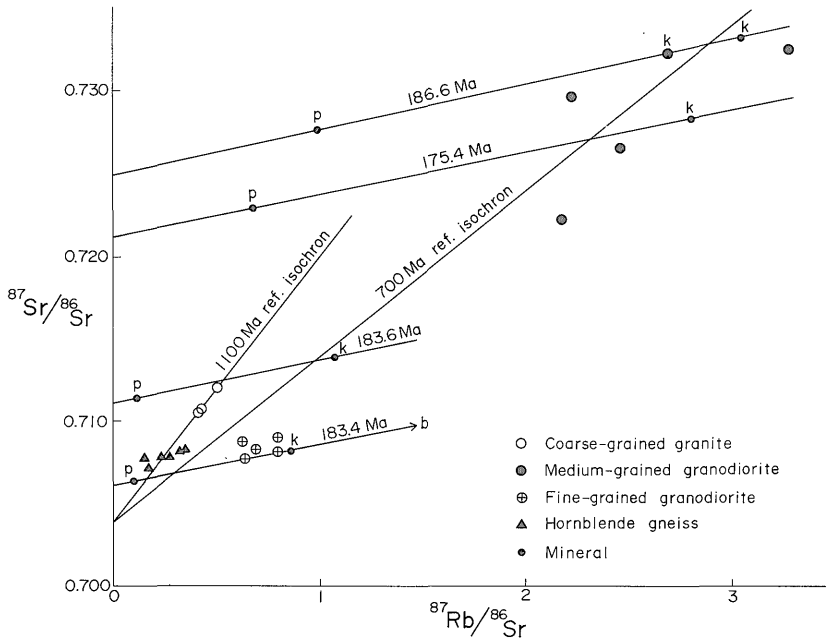

Fig. 3 Rb-Sr isochron plot for granitic and metamorphic rocks at Kagasawa.
Reference isochrons of 1100 Ma and 700 Ma for the coarse-grained granite and medium-grained granodiorite, respectively, and mineral isochrons for four granitic rocks are shown; k: K-feldspar, p: plagioclase, b: biotite.

scatter of the points reflects the opening of Rb-Sr whole-rock system during a later metamorphism. However, the disturbance was limited to the rock volume of hand specimen size, thus it is probable that the medium-grained granodiorite is originated in the latest Precambrian.

Fine-grained granodiorite

There is a scatter of points beyond the experimental error despite similar $^{87}Rb/^{86}Sr$ ratios of the samples. However, the results clearly indicate that the fine-grained granodiorite has much less radiogenic ^{87}Sr and must be much younger than the above-mentioned two types of rocks, the fact of which is consistent with the field evidence that the former is intruded by the latter, and that biotite is fresher in the former. The model ages, assuming the initial ratio as 0.705, are calculated to be 280-420 Ma, although they are much influenced by the value of initial ratio. In any case, this rock, together with other rocks at Kagasawa, must have been involved and disturbed with respect to the Rb-Sr system in the major regional metamorphism that took place at 250-220 Ma in the Hida Metamorphic Belt (SHIBATA *et al.*, 1970).

Hornblende gneiss

The gneiss is the oldest at this locality, as it is intruded by all types of granitic rocks. Yet the data points show no sign of old origin, therefore the Rb-Sr whole rock system must have been opened during later events. This rock is composed of plagioclase, quartz, hornblende, and biotite with minor amount of K-feldspar, thus the main carrier of Rb is biotite. Possibly the radiogenic ^{87}Sr accumulated in biotite was removed, at least partly, from the whole-rock system. An apparently younger isochron age of about 440 Ma defined by five samples (excluding BC78-3) may be the result of the open-system behavior.

Mineral ages

Rb-Sr mineral isochron ages determined on four samples are given in Fig. 3. Ages for

Table 3 K-Ar ages of minerals for granitic and metamorphic rocks at Kagasawa.

Sample No.	Mineral	K_2O (%)	^{40}Ar rad (10^{-6} mlSTP/g)	Atm. ^{40}Ar (%)	Age (Ma)
1203D	Biotite	1.33	5.89	73.0	132±9
	K-feldspar	6.90	35.8	22.8	153±5
1203A	Hornblende	0.673	5.16	30.6	223±8*

* SHIBATA and NOZAWA (1978)

samples 2901E (coarse-grained granite) and 2901B (medium-grained granodiorite) are 183.6 and 175.4 Ma, respectively, which are calculated from Rb-Sr data of plagioclase (+quartz) and K-feldspar, because the whole-rock point does not fall on the line connecting plagioclase and K-feldspar. In both cases the whole-rock system may have been partially opened. 1203D (medium-grained granodiorite) gives an isochron age of 186.6 ±14.2 Ma by plagioclase, whole-rock and 2 K-feldspars. Chloritized biotite of this sample gives much younger age of 106 Ma assuming an initial ratio of 0.725. Sample 1203B (fine-grained granodiorite) gives an isochron age of 183.4±2.8 Ma by plagioclase, whole-rock, K-feldspar and biotite.

All these ages are within a limited range of 175–187 Ma, regardless of rock types, and essentially the same as that of the Funatsu Granitic Rocks, which give a Rb-Sr whole-rock isochron age of 189 Ma (SHIBATA and NOZAWA, 1984) and many mineral ages of 170–190 Ma. Accordingly, it is certain that all rocks at Kagasawa were subjected to the thermal effect by the intrusion of the Funatsu Granitic Rocks.

K-Ar ages determined for rocks at Kagasawa are given in Table 3. K-Ar age of biotite for 1203D is slightly older than Rb-Sr age, but still much younger than the Rb-Sr mineral isochron age. K-Ar age of hornblende for 1203A (hornblende gneiss), which was dated as 223 Ma by SHIBATA and NOZAWA (1978), is older than the Rb-Sr mineral isochron ages. In fact, this age is close to that of the major metamorphism in the Hida Metamorphic Belt, and confirms that the rocks at Kagasawa were subjected to this metamorphism. The closure temperature for hornblende K-Ar system is estimated to be about 500°C (e.g., HARRISON, 1981). Probably the rocks at Kagasawa were not heated much above 500°C by the Funatsu Granitic Rocks.

Discussion

Rb-Sr model ages on three granitic dikes; coarse-grained granite, medium- and fine-grained granodiorites, suggest three stages of plutonism at about 1100, 700 and 300 Ma, respectively, in accordance with the mutual contact relation. These age results indicate that the coarse- and medium-grained granitic rocks, together with hornblende gneiss, originated in late Precambrian time. Also important is the polymetamorphism on these rocks which must be very complicated according to the age results. Polymetamorphism in the Hida Metamorphic Belt was postulated by SATO (1968) and SUZUKI (1977) on the basis of geologic and petrographic evidence and limited age data. Sato's argument is based on a preliminary Rb-Sr age data reported by SATO *et al.* (1967) on granitic rocks in the Hida Metamorphic Belt. A gray granite, which is similar in rock type to the coarse-grained granite at Kagasawa, yielded Rb-Sr whole-rock, K-feldspar and biotite ages of 1200, 810, and 680 Ma, respectively. It is diffucult to assess these ages, since no analytical data have been published. Yet it is interesting to note that the age for whole-rock, which was supposedly calculated by assuming a certain value of initial $^{87}Sr/^{86}Sr$ ratio, is similar to the model ages for the coarse-grained granite. However, the age of

K-feldspar has no geological meaning as Sr isotopic homogenization between minerals occurred during a later event as shown in the rocks at Kagasawa.

Another evidence for the Precambrian origin of the Hida Metamorphic Rocks is suggested by Pb ages of gneiss. The $^{207}Pb/^{206}Pb$ ages of 1493 Ma (ISHIZAKA and YAMAGUCHI, 1969) on a detrital zircon and 764 Ma (SHIBATA *et al.*, 1970) on a sphene-zircon mixture both from the Amo gneiss clearly indicate that the rocks contain the material originated in Precambrian time, although these ages do not necessarily represent the time of metamorphism for the gneiss.

The late Paleozoic plutonism in the Hida Metamorphic Belt is demonstrated on the Mizunashi Granite from the Amo area which was dated as 296.7 Ma (SHIBATA and NOZAWA, 1984), and on tonalite from the Urushiyama area dated as 332 Ma (ARAKAWA, 1984), both by Rb-Sr whole-rock isochron method. The locality of the tonalite is about 7 km southeast of Kagasawa. Although the petrography and intrusive feature of the tonalite is different from that of the fine-grained granodiorite at Kagasawa and the Mizunashi Granite, the similarity in age may suggest the occurrence of plutonism on a regional scale at about 300 Ma.

Two important problems will be discussed in the light of the newly obtained geochronological data. One is whether or not each of three plutonic activities was associated with the contemporaneous regional metamorphism. The hornblende gneiss must have been metamorphosed at least as old as about 1100 Ma, but there is no other evidence to suggest the correlation between the Precambrian plutonism and metamorphism. It is also difficult to assess the 300 Ma metamorphism, as any reliable mineral ages around 300 Ma were reported nowhere in the Hida Metamorphic Belt. Thus we have no definite evidence to postulate the close relationship between the plutonism and metamorphism, although it is possible to correlate the earlier high-grade metamorphism such as proposed by SATO (1968) and SUZUKI (1977) with the plutonism at about 1100 Ma or 700 Ma.

Another problem concerns the extent of the Precambrian plutonism in the Hida Metamorphic Belt. The age data discussed in this paper are obtained on rocks from a single outcrop. However, considering the common occurrence of hornblende gneiss and coarse-grained granite that can be identified as gray granite, at least the middle part of the Miyagawa Mass may have been involved in the Precambrian plutonism. Detailed geochronological study on the gray granite in the Miyagawa Mass will help clarify the complex history of Precambrian plutonism and metamorphism in the Hida Metamorphic Belt.

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飛騨変成岩類に貫入する花崗岩類の後期先カンブリア年代

柴田　賢・野沢　保

要　旨

飛騨山地加賀沢における飛騨変成帯中の花崗岩質岩脈及び角閃石片麻岩について，Rb-Sr 全岩法による年代測定を行った．ここでは3種類の岩脈，すなわち粗粒花崗岩，中粒花崗閃緑岩及び細粒花崗閃緑岩が，この順序で片麻岩に貫入している．これらの花崗岩類は後の時代の地質事変の影響を受けて，正確なアイソクロン年代を示さない．しかし Rb-Sr モデル年代として約1100, 700, 300 Ma という値が得られた．この結果は粗粒花崗岩と中粒花崗閃緑岩が片麻岩と共に，後期先カンブリア時代の起源をもつことを示している．

花崗岩類と片麻岩の鉱物年代は，加賀沢の岩石が250-220 Ma の変成作用を受け，さらに船津花崗岩類の貫入による熱的影響を受けていることをうらづける．

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