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Origin of granitic rocks at the southern margin of the Ryoke belt in the Mikawaono-Toei area, central Japan: Rb-Sr dating and tectonic implications.*

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Abstract Rb-Sr age determinations were carried out on some granitic rocks(the Ohshima granite, the Aikawa tonalite and the Asakawazawa granite) of the Ryoke nappe complex in the Mikawaono-Toei area, situated in the southern low-grade segment of the Ryoke metamorphic belt. The Ohshima granite as a younger Ryoke granite, has a Rb-Sr mineral isochron age of 79.3±0.9Ma. The Aikawa tonalite, which is a mylonitized older Ryoke granite, has a Rb-Sr whole-rock isochron age of 72.3±14.1 Ma and a mineral isochron age of 65.9±14.6Ma, which may show later isotopic disturbance. The Asakawazawa granite has a Rb-Sr whole-rock isochron age of 151.6±18.3Ma recording its mylonitization, and a whole-rock isochron age of 61.5±1.4Ma and a mineral isochron age of 62.2±3.0Ma correlating with a later cataclastic event. On the basis of the Rb-Sr dating of granitic rocks, it has been concluded that the Ryoke nappe complex in this area contains the Ryoke phase components(the Ohshima granite and the Aikawa tonalite) and a pre-Ryoke phase component(the Asakawazawa granite), derived from the Ryoke belt and the Paleo-Ryoke land.

Key word: Ryoke belt, granitic rock, Rb-Sr dating, nappe, late Jurassic granite, Paleo-Ryoke land

Introduction

The Ryoke belt is a typical high-temperature metamorphic belt with acidic magmatism. The original metamorphic rocks of the Ryoke belt have generally been considered a southern extension of the Jurassic and earliest Cretaceous accretionary complexes of the Tamba-Mino Terrane, suggesting that the high temperature metamorphism and acidic magmatism in the Ryoke belt began after the formation of these complexes.

The northern and the southern margins of the Ryoke metamorphic belt are comprised of low-grade rocks. Thus, the highest tem-perature axis of the Ryoke metamorphism has been interpreted to be along the central part of the belt(Miyashiro, 1959; Suwa, 1961, 1973). However, it has recently been clarified that the Ryoke metamorphic and igneous rocks along the southern margin of the belt generally form nappes in the region between Sakuma and Mikawaono, central Japan(Ohtomo, 1987, 1989, 1990), in the Kayumi district, Kii Peninsula (Sakakibara *et al.*, 1989), in the Asaji district (Hayasaka *et al.*, 1989)and in the Kosa district, Kyushu(Okamoto *et al.*, 1989). Ohtomo(1990, 1991)and Sakakibara *et al.*(1989)clarified that the nappes of the high-grade metamorphic and granitic rocks overlie the low-grade ones and non-metamorphic sediments developed along

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the southern margin of the Ryoke belt.

The Ryoke belt between Mikawaono and Toei, Aichi Prefecture, forms part of the southern low-grade metamorphic segment. This area apparently juts out onto the Sambagawa belt along the Median Tectonic Line(MTL)(Fig.1). As shown in Fig.1, the Ryoke belt in this area is divided into eight units - the Asakawazawa formation, the Asakawazawa granite, the Aikawa tonalite, the Ohshima granite, the Nanasato-isshiki formation, the Suyama pyroclastic rocks, cataclasite, and the Atera Nanataki conglomerate(Ohtomo, 1990). The former six units form nappes. The cataclasite was formed as crush melange from these unitsdeveloped with a low-angle obliquity to the nappe structure. The deformation related to the formation of the cataclasite produced new nappes along their boundaries(Fig. 1). The nappes are nearly horizontal on the Sambagawa belt(Hara *et al.*, 1980), and have NE-SW trending upright folds, which predate the deposition of the Atera Nanataki conglomerate and the Shidara Group (Ohtomo, 1990). Ui(1980)correlated the Atera Nanataki conglomerate to the Upper Cretaceous Izumi Group, and Hayashi & Koshimizu (1992)recently reported Eocene molluscs from the lower sequence(the Hokusetsu Subgroup)of

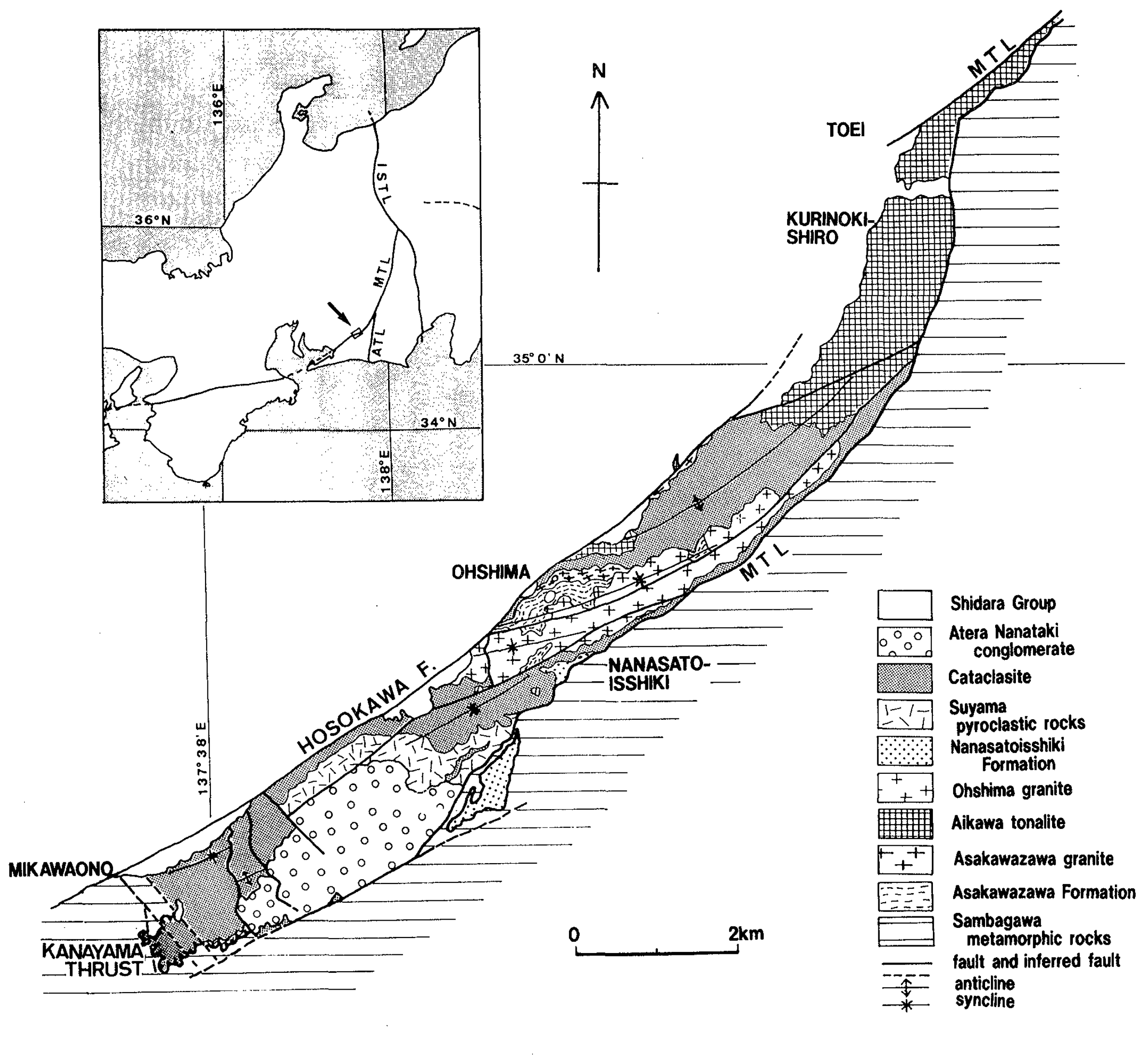

Fig. 1. Geologic map of the Mikawaono-Toei area(Ohtomo,1990). MTL:Median Tectonic Line, ATL:Akaishi Tectonic Line, ISTL:Itoigawa-Shizuoka Tectonic Line.

the Shidara Group. To the east of Mikawaono, sandstone and mudstone of the Hokusetsu Subgroup lie unconformably on the cataclasite. The pile nappe units were named the Ryoke nappe complex; while the boundary between the complex and the Sambagawa rocks the Kanayama thrust(Ohtomo, 1990). Until now, rocks in the area have been regarded as the members of the Ryoke belt. However their origins have not been fully clarified. In general, age data are a key to determine the origin of rock. Fission-track dating for the Suyama pyroclastic rocks gave ages in the latest Cretaceous(Yamada *et al.*, 1987). Ages for the other units have not been measured. A description of the results of Rb-Sr dating of the Ohshima granite, the Aikawa tonalite, and the Asakawazawa granite, and a discussion of their tectonic implications are provided in this paper.

Granitic rocks in the Ryoke nappe complex

A schematic profile displaying the tectonic superposition of the Ryoke nappe complex and the Sambagawa belt is illustrated in Fig. 2. There are three granitic rock bodies - the Ohshima granite, the Asakawazawa granite, and the Aikawa tonalite in descending order of structural level. Geologic and petrographic characteristics of these granitic rocks are briefly described below.

The distribution pattern of the Ohshima granite indicates that it forms a nappe over the Asakawazawa Formation and/or the Asakawazawa granite(Fig.3b). The Ohshima granite is a coarse - grained, massive biotite granite. It consists mainly of quartz, K-feldspar, plagioclase, and biotite with accessory zircon, apatite, and opaque minerals. The granitic texture is completely preserved in the upper portion of the granite nappe, though the quartz grains show undulatory extinction. The lower portion of the granite nappe along the nappe boundary has been strongly mylonitized. The mylonitized rocks frequently exhibit mylonitic foliation, which is defined by elongation of quartz domain. Quartz is deformed plastically, producing well-developed ribbon structures with deformation bands at high angles to the ribbon boundaries. Plagioclase and K-feldspar grains show grain size reduction by micro-cracking

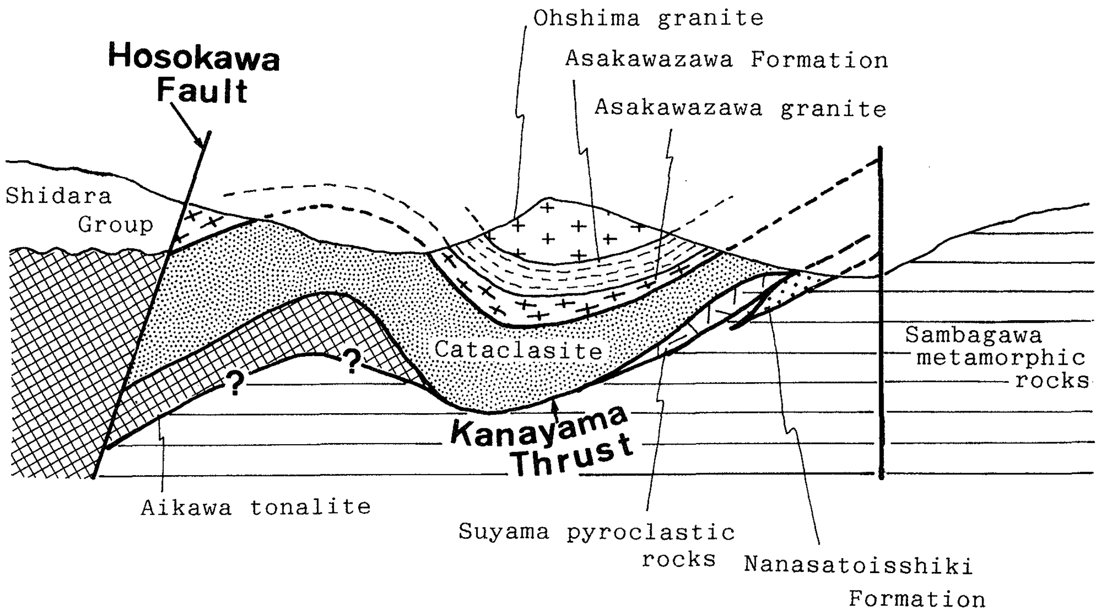

Fig. 2. Schematic geologic cross-section of the Ryoke nappe complex in Mikawaono-Toei area (Ohtomo, 1990).

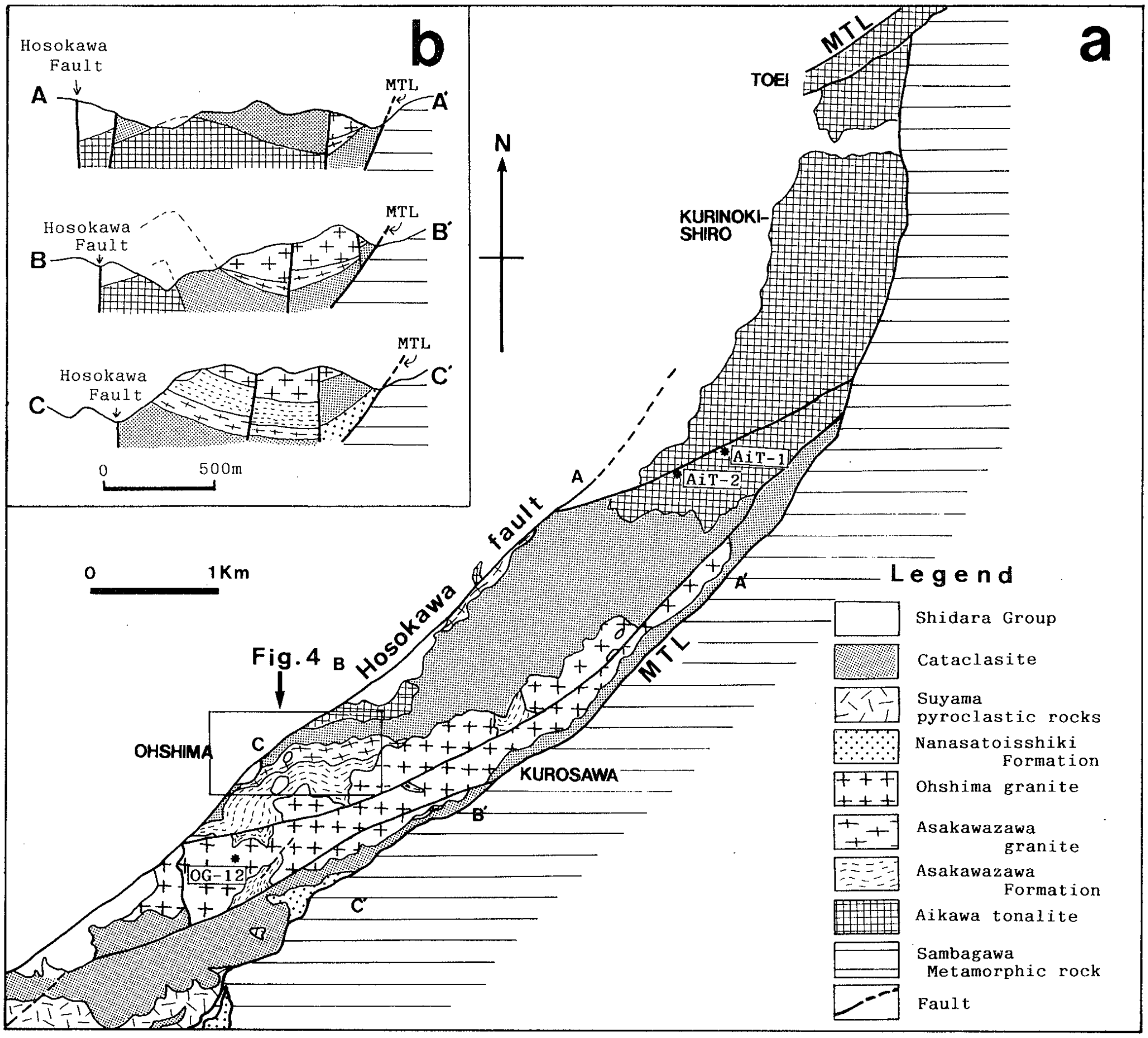

Fig. 3. a: Location map of the analyzed samples from the Ohshima granite and the Aikawa tonalite. b: Geologic sections.

and microfaulting. In highly strained rocks, biotite disappears, and fine-grained chlorite and sericite occur with their (001) planes subparallel to the mylonitic foliation. Mylonitization is therefore roughly presumed to have occurred under lower greenschist facies conditions during the deformation related to the formation of the Ohshima granite nappe (Ohtomo, 1993).

The Aikawa tonalite is overlain and cut by the cataclasite zone (Fig. 3b). The tonalite is composed of mylonitic rocks derived mainly from tonalite with subordinate granite. The mylonite derived from tonalite is composed of minerals such as quartz, plagioclase, biotite, hornblende, and ±K-feldspar, with accessory sphene, allanite, epidote, zircon and apatite. The granitic mylonite always consists of quartz, K-feldspar, plagioclase and biotite with the same accessory minerals as the tonalite mylonite. All constituent minerals are dynamically recrystallized, resulting in grain size reduction. Mylonitization occurred under amphibolite facies conditions. Strongly-deformed rocks display mylonitic foliation and lineation. The mylonitic foliation is defined by dimensional preferred orientation of elliptical porphyroclasts and fluxion banding, characterized by elongate pressure shadows, and is commonly parallel to the original compositional banding. Intrafolial folds of the foliation are often observed in the banded mylonites. The mylonite can be correlated with the Hiji tonalite (mylonite) based on geologic and petrographic characteristics (e.g., Hara *et al.*, 1980; Takagi, 1986).

The Asakawazawa granite underlies both the Asakawazawa Formation and the Ohshima granite nappe and is cut by underlying cataclasite zone (Fig. 3b). The Asakawazawa granite consists mainly of granite with subordinate tonalite. It has a mylonitic texture, with mylonitic foliation and lineation, and contains quartz, K-feldspar, plagioclase and biotite, with accessory zircon, apatite and opaque minerals. Most of the biotite was replaced by chlorite. The mafic minerals of the tonalite were also replaced by chlorite and epidote. The mylonitic foliation is characterized by mineralogical layering of alternating quartz layers and feldspar layers. The quartz shows well-developed ribbon structures with some recrystallized new grains. The ribbon boundaries are irregular and serrated. The elongate grain shapes and grain boundary alignments of quartz grains are oblique to the foliation. Plagioclase and K-feldspar are dynamically recrystallized to a fine-grained mosaic texture and show subgrains along grain margin. It can be suggested that mylonitization is presumed to have occurred at amphibolite facies condi-tions, because of the dynamic recrysta-llization of feldspars. The lower part of Asakawazawa granite is strongly affected by cataclastic deformation which postdates the mylonitization. Cataclasis is manifested in the formation of numerous calcite veinlets and secondary mineral alterations such as sericitization of plagioclase and K-feldspar, and chloritization of biotite.

Analyzed samples

Samples from the Ohshima granite, the Aikawa tonalite and the Asakawazawa granite were collected at the locations shown in Figs. 3a and 4. A whole-rock sample was taken from the Ohshima granite. This sample was only slightly deformed forming deformation lamellae in quartz. Biotite is partially chloritized. K-

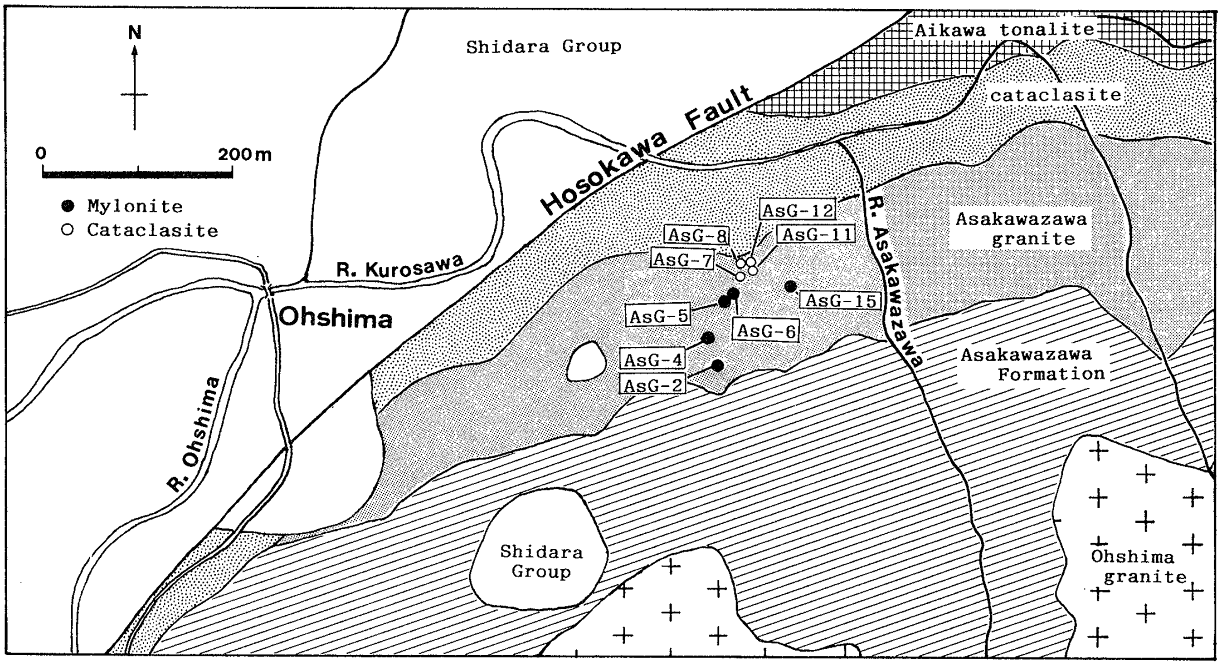

Fig. 4. Location map of the analyzed samples from the Asakawazawa granite.

feldspar and plagioclase were separated from this sample for age determination.

Two samples, AiT-1 and AiT-2, were taken from the Aikawa tonalite. Both have a compositional layering with a thickness of about several cm (Fig. 5) and a well-developed mylonitic texture. The mylonitic foliation is subparallel to the layering. The sample AiT-1 is divided into five whole-rock samples (AiT-1A~E), which were taken from five different layers respectively, as shown in Fig. 5. The layer of sample AiT-1A looks like a dyke, which may have predated the myloniti-zation. This is because the layer has granitic inclusions which were mylonitized with the dyke forming a continuous mylonitic foliation. Two whole-rock samples, AiT-2A and 2B, were also taken from the sample AiT-2. K-feldspar and plagioclase

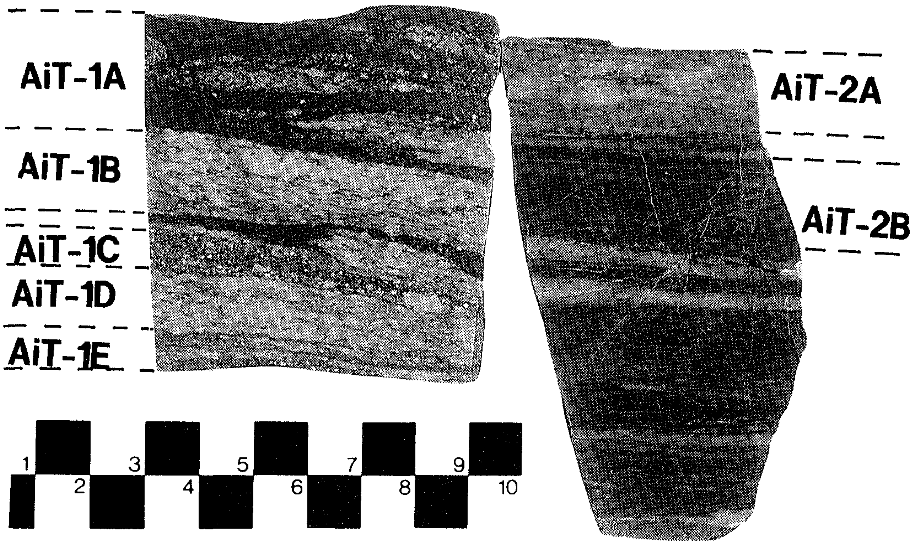

Fig. 5. Photograph of the analyzed samples of the Aikawa tonalite. Scale=1cm.

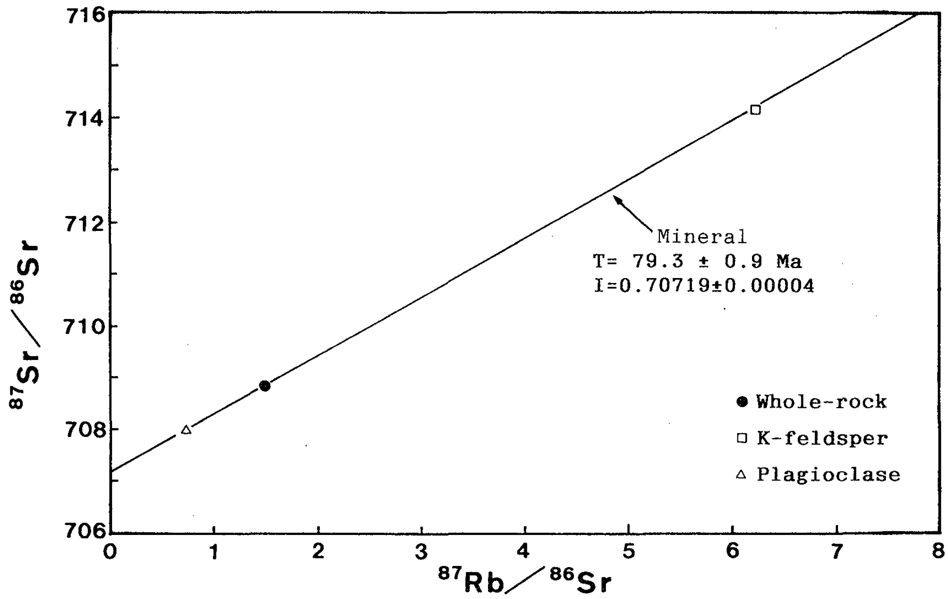

Fig. 6. Isochron diagram for the Ohshima granite.

were separated from the layer of AiT-2A. These mineral samples are composed of a mixture of porphyroclasts and fine, recrystallized grains.

Nine whole-rock samples were collected from the Asakawazawa granite. Five of these samples(AsG-2, 4, 5, 6 and 15)are from the upper mylonitic portion(Fig. 4). The other four samples(AsG-7, 8, 11 and 12)were collected from the lower cataclastic portion(Fig. 4), in order to investigate the effect of later deformation. The Rb and Sr isotopic compositions were also analyzed from two minerals(plagioclase and K-feldspar)which were separated from AsG-5.

Analytical techniques and results

These seventeen whole-rock and six mineral samples were analyzed isotopically. Rb and Sr concentrations were determined by X-ray fluorescence and isotope dilution using a ^{87}Rb-^{86}Sr mixed spike. Rb and Sr were separated following the procedure described by Kagami *et al.* (1982, 1987). The extracted elements were loaded onto a Ta-filament in a double filament mode. Mass spectrometric analyses were made using a MAT261 mass spectrometer. $^{87}Sr/^{86}Sr$ ratios were normalized to $^{86}Sr/^{88}Sr=0.1194$. Sr isotopic ratios for NBS987 were measured seven times during this study. The average ratio was 0.710252 ± 0.000015 (2σ). Rb-Sr whole-rock isochron ages were calculated using the equation of York(1966)and $\lambda^{87}Rb=1.42\times10^{-11}y^{-1}$ (Steiger & Jäger, 1977).

The Rb-Sr data are given in Table 1 and isochron diagrams in Figs. 6, 7 and 8. The following age calculations have been made:

Ohshima granite

The mineral samples(K-feldspar and plagioclase) and the whole-rock sample form an isochron which indicates an age of 79.3 ± 0.9Ma with a MSWD(mean square of weighted deviates)of 0.02 and an SrI ($^{87}Sr/^{86}Sr$ initial ratio)of 0.70719 ± 0.00004 (2σ).

Aikawa tonalite

The five data points for sample AiT-1 give an isochron age of 79.6 ± 14.0 Ma(MSWD=0.11) with an SrI of 0.70699 ± 0.00018 (2σ). If the one data point(AiT-1A)is excluded from the regression(for AiT-1A looks like a mylonite derived from a dyke intruded into the granite), the four remaining data points define an isochron age of 72.3 ± 14.1Ma(MSWD=0.07)with an SrI of 0.70711 ± 0.00020 (2σ). The data points of the

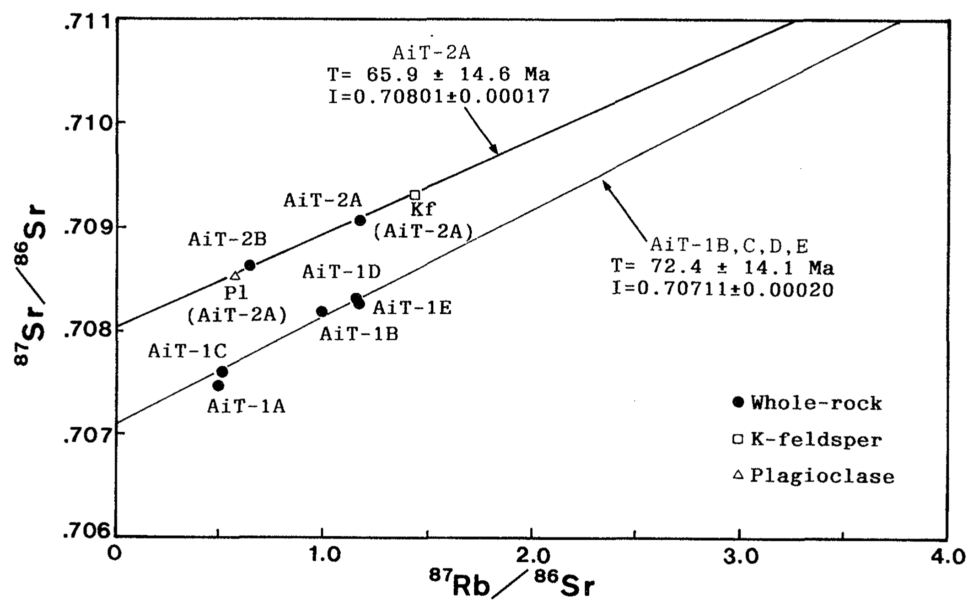

Fig. 7. Isochron diagram for the Aikawa tonalite.

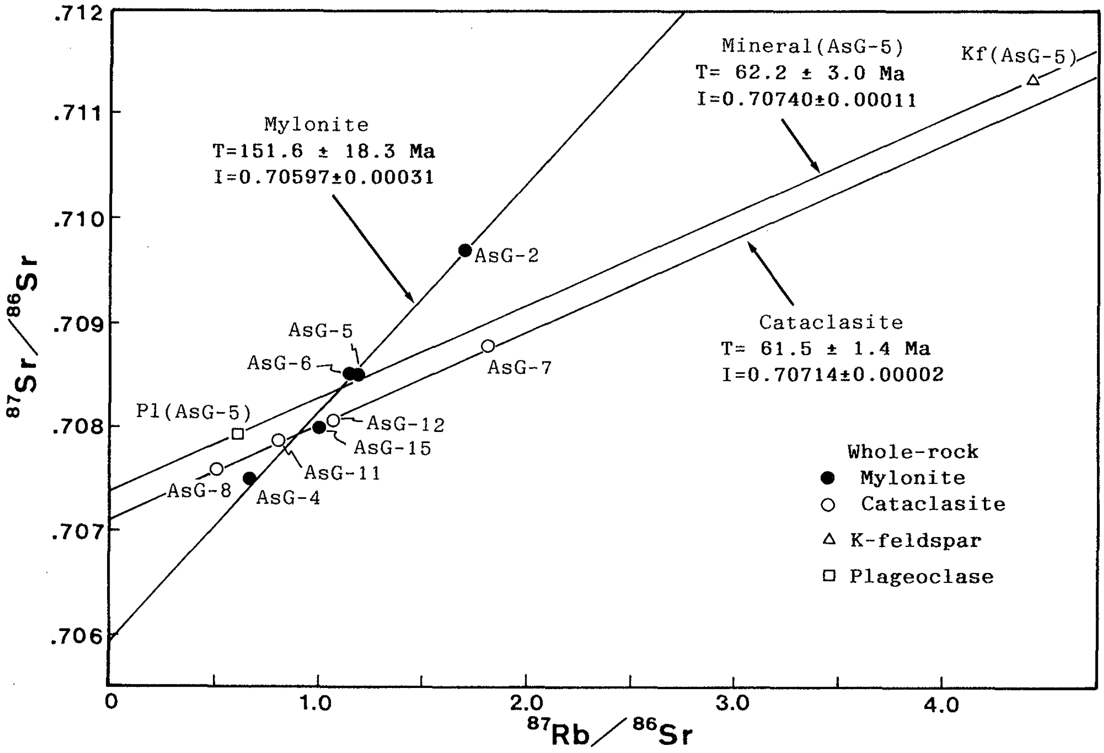

Fig. 8. Isochron diagram for the Asakawazawa granite.

whole-rock sample(AiT-2A)and mineral samples(K-feldspar and plagioclase)define a mineral isochron age of 65.9 ± 14.6Ma(MSWD =0.20)with an SrI of 0.70801±0.00017 (2σ). The whole-rock sample of AiT-2B is plotted near the mineral isochron of AiT-2. As shown in Fig. 7, AiT-1 and AiT-2 form different isochrons.

Asakawazawa granite

These whole-rock samples fall into two distinct groups. One group defines an isochron corresponding to an age of 151.6 ± 18.3Ma (MSWD=0.27)with an SrI of 0.70597 ± 0.00031 (2σ), whereas the other group gives a good-fit isochron indicating an age of 61.5 ± 1.4Ma (MSWD=0.02)and an SrI of 0.70714 ± 0.00002 (2σ). The former are taken from the upper portion of the Asakawazawa granite nappe, the latter from the lower portion affected by later cataclastic deformation.

The data points of the mineral samples(K-feldspar and plagioclase)and the whole-rock sample for AsG-5 define an isochron age of 62.2±3.0 Ma(MSWD=0.13)with an SrI of 0.70740 ±0.00011 (2σ). This is similar to the whole-rock isochron age from the lower cata-clastic portion of the granite nappe.

Discussion

Interpretation of Rb-Sr isotopic ages

Ohshima granite

A mineral isochron age of 79.3 Ma is obtained for the Ohshima granite. Generally, mineral ages represent the time of crystallization of a mineral, cooling to a temperature at which a mineral system becomes closed, or a later metamorphic event. Although the Ohshima granite underwent mylonitization near its nappe base, it is clear, from petrographic observations, that the analyzed sample escaped the deformation. The Ohshima granite is generally massive without a gneissose structure which is characteristic of the older Ryoke granites. The SrI of 0.70719 for the granite is within the range for that of other Ryoke granites. The Ohshima granite is regarded as one of the younger Ryoke granites, as its mineral age of 79.3 Ma is considered to be either the time of crystallization or that of cooling.

Aikawa tonalite

A mineral isochron age of 65.9 Ma and whole rock isochron age of 72.3 Ma were obtained for different samples of the Aikawa tonalite.

There is a possibility that the whole rock isochron age is closely related to the time of formation of a suit of comagmatic rocks in the Aikawa tonalite. But it is doubtful that it actually recorded this date because, under amphibolite facies conditions, the Aikawa tonalite underwent mylonitic deformation showing dynamic recrystallization and drastic grain size reduction of its constituent minerals. Such deformation increases intracrystalline strain energy and enhances intracrystalline diffusion (Cohen, 1970; Brodie, 1980 etc.). Additionally grain size reduction greatly increases diffusion along grain boundaries (cf. Beach, 1980).

K-Ar ages of 56-38 Ma in the Takato area (Shibata & Takagi, 1988) and Ar-Ar ages of 62-63 Ma in the Kashio area (Dallmeyer & Takasu, 1991) have been reported for the Hiji tonalite (mylonite) which is correlated with the Aikawa tonalite. But the K-Ar ages of the Katsuma quartz diorite, which intrudes the Hiji tonalite subsequent to mylonitization, are 70 Ma (hornblende) and 63 Ma (biotite). Because of a whole rock Rb-Sr age of about 90 Ma from the non-mylonitized Hiji tonalite from some selected area (Yamana *et al.*, 1983), the main stage of mylonitization is interpreted to have occurred at between 90-70 Ma (Shibata & Takagi, 1988). Additionally, as a non-deformed younger Ryoke granite (the Nojima granodiorite) of 87.7 Ma intrudes into mylonite in Awaji Island, mylonitization is considered to have occurred before 87.7 Ma (Takahashi, 1992). We thus cannot regard the isochron ages of 72.3 Ma and 65.9 Ma for the Aikawa tonalite as mylonitization ages. The AiT-2 sample, carrying the mineral isochron age of 66 Ma, contains low-grade mineral alteration (for example saussuritization of plagioclase and chloritization of biotite). The Rb-Sr ages of the Aikawa tonalite may have been related to the resetting of the Rb-Sr isotopic system which is due to a low-grade geological event after the mylonitization. An exact interpretation of the age data from the Aikawa tonalite remains undetermined.

Asakawazawa granite

The whole-rock age of 151.6 Ma from the upper mylonitic portion is considered to show the time of mylonitization according to the following argument. The analyzed Asakawazawa granite has a penetrative mylonitic deformation, which resulted in dynamic recrystallization and drastic grain size reduction of its constituent minerals. Both plagioclase porphyroclasts and dynamically recrystallized plagioclase in the granite facies have the same chemical composition (An_{13-17}). The cores of the plagioclase in the non-mylonitized granitic rocks of the Ryoke belt generally have an An content of more than 30 percent (e.g., Yamada *et al.*, 1977). The chemical composition of the plagioclase in the Asakawazawa granite may have greatly changed during mylonitization. The K-feldspar porphyroclasts in the Asakawazawa granite have a composition of Or_{84-97}, while the dynamically recrystallized K-feldspar have Or_{94-97} compositions. The latter indicates that the chemical composition of K-feldspar changed during mylonitization. The mineral constituents in the Asakawazawa granite appears to have undergone modification in their chemical compositions due to intracry-stalline diffusion during the mylonitization. Diffusion along grain boundaries may also have been greatly increased by grain size reduction (cf. Beach, 1980). Thus, the process of mylonitization may have caused resetting of the Rb-Sr whole-rock system (cf. Smalley *et al.*, 1983). However, the time of intrusion of the Asakawazawa granite is not likely to have been much older than 151.6Ma, because dynamic recrystallization of plagioclase occurs at a temperature higher than 500℃ (cf. Tullis & Yund, 1977), and the granite was still at a high temperature favorable for recrystallization of plagioclase during the mylonitization. Based on this data and the discussion, it can be assumed that the time of the intrusion of the Asakawazawa granite is late Jurassic.

The whole-rock age of 61.5 Ma from the lower cataclastic portion is remarkably younger than the one from the upper mylonitic portion. According to Smalley *et al.* (1983), the Rb-Sr whole-rock system can be reset resulting from even relatively low-grade mineral alteration by hydrous fluids (for example sericitization and saussuritization of plagioclase). The whole-rock age of 61.5 Ma is therefore considered to be related to the resetting of the Rb-Sr whole-rock system during cataclastic defor-mation. The minerals, which were sepa-rated from AsG-5, yield an isochron age of 62.3 Ma. The mineral age from the upper mylonitic portion is similar to the whole-rock age from the lower cataclastic portion. The mineral isochron age of 62.4 Ma may also be a result of a resetting of the Rb-Sr system. Therefore, it can be emphasized that the jointing of the Ryoke belt and of the Sambagawa belt, which followed the formation of the Ryoke nappe complex, occurred during the earliest Paleogene time. Dallmeyer & Takasu (1992) also suggested that the tectonic juxtaposition of the Sambagawa and the Ryoke belt occurred in the Middle Paleocene, based on the fission-track ages of 54-58 Ma of Tagami *et al.* (1988).

Table 1. Rb-Sr data of the Ohshima granite, the Aikawa tonalite and the Asakawazawa granite.

sample		Rb(ppm)	Sr(ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr(2\sigma)$*
Ohshima granite					
Q1-12	Whole-rock	90.3	174.3	1.4988	0.70890(2)
Q1-12	K-feldspar	281.9	131.4	6.2135	0.71419(1)
Q1-12	Plagioclase	69.2	272.3	0.7352	0.70801(2)
Aikawa tonalite					
AiT-1A	Whole-rock	53.0	315.0	0.4870	0.70748(3)
AiT-1B	Whole-rock	67.2	195.1	0.9967	0.70818(3)
AiT-1C	Whole-rock	60.0	338.9	0.5122	0.70762(2)
AiT-1D	Whole-rock	75.9	190.3	1.1535	0.70831(1)
AiT-1E	Whole-rock	78.0	192.2	1.1745	0.70826(2)
AiT-2A	Whole-rock	94.3	231.4	1.1795	0.70900(1)
AiT-2A	K-feldspar	122.7	254.8	1.3939	0.70931(2)
AiT-2A	Plagioclase	37.4	187.5	0.5766	0.70852(2)
AiT-2B	Whole-rock	90.0	405.9	0.6419	0.70865(2)
Asakawazawa granite					
AsG-2	Whole-rock	111.2	188.2	1.7094	0.70970(2)
AsG-4	Whole-rock	75.5	325.1	0.6721	0.70750(1)
AsG-5	Whole-rock	86.6	209.8	1.1936	0.70850(1)
AsG-5	K-feldspar	266.9	173.9	4.4426	0.71132(2)
AsG-5	Plagioclase	39.1	182.8	0.6188	0.70791(2)
AsG-6	Whole-rock	69.1	171.8	1.1639	0.70851(1)
AsG-7	Whole-rock	94.6	150.5	1.8190	0.70873(1)
AsG-8	Whole-rock	64.4	368.6	0.5053	0.70758(1)
AsG-11	Whole-rock	64.5**	232.6**	0.8023	0.70785(2)
AsG-12	Whole-rock	103.5**	280.9**	1.0661	0.70806(1)
AsG-15	Whole-rock	71.9**	207.3**	1.0035	0.70800(2)

* Numbers in parentheses for the $^{87}Sr/^{86}Sr$ ratios refer to the 2σ error in the last digit. ** Rb and Sr by XRFS; others by isotopic dilution.

Origin of the Asakawazawa granite

The Ryoke metamorphism and igneous activity occurred after the formation of late Jurassic-earliest Cretaceous accretionary complexes of the Mino-Tamba Terrane. As discussed above, the igneous activity and mylonitization of the Asakawazawa granite occurred at about 152 Ma (latest Jurassic age). Osanai *et al.* (1992) have also reported Jurassic age (164Ma) granite (the Yamanaka granodiorite) in the Ryoke belt of the Asaji area, Kyushu. This igneous activity did not occur in the Inner Zone of Southwest Japan. Both the Asakawazawa granite and the Yamanaka granodiorite indicate that the Ryoke belt contains a conti-nental mass on which late Jurassic acidic magmatism occurred. The presence of the Paleo-Ryoke land, which was situated on the southern side of the Ryoke belt during Jurassic time, has been proposed by various workers, such as Ichikawa (1964), Hayama (1991) and Hara *et al.* (1991, 1992). It can be concluded that the Ryoke belt is a collision zone of the Jurassic-earliest Cretaceous accretionary complexes and the continental mass (Paleo-Ryoke land).

Summary

1. The Ohshima granite has a Rb-Sr mineral isochron age of 79.3±0.9 Ma and correlates with the younger Ryoke granite.

2. The Aikawa tonalite, a mylonitized older Ryoke granite, has a Rb-Sr whole-rock isochron age of 72.3±14.1 Ma and a mineral isochron age of 65.9±14.6 Ma. These ages are too young to correlate with the time of mylonitization and therefore must have been affected by some later isotopic disturbance.

3. The Asakawazawa granite has a Rb-Sr whole-rock isochron age of 151.6±18.3 Ma as timing of mylonitization, and a mineral isochron age of 62.2±3.0 Ma, and a whole-rock isochron age of 61.5±1.4 Ma correlated with a later cataclastic event.

4. On the basis of Rb-Sr dating of the granitic rocks, the Ryoke nappe complex includes granitic rocks derived from the Ryoke belt and the Paleo-Ryoke land.

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* in Japanese
** in Japanese with English abstract

中部地方，三河大野－東栄地域において領家帯南縁の岩石はナップをなして三波川帯の上位に水平的にのっている．この地域の領家ナップコンプレックスの花崗岩質岩(大島花崗岩・相川トーナル岩・浅川沢花崗岩)のRb-Sr年代を測定した．大島花崗岩は79.3±0.9Maの鉱物年代を示し，領家新期花崗岩に対比される．領家古期花崗岩の相川トーナル岩は72.3±14.1Maの全岩年代と65.9±14.6Maの鉱物年代が得られたが，後の時期の影響を受けていると考えられる．浅川沢花崗岩は151.6±18.3Maのマイロナイト化の時期を示すと考えられる全岩年代と，61.5±1.4Maのカタクラサイト化の時期に対応する全岩年代が得られた．マイロナイトの鉱物年代は62.2±3.0Maでカタクラサイト化作用による影響を受けている．領家ナップコンプレックスには領家帯の花崗岩(大島花崗岩・相川トーナル岩)だけでなく，先領家大陸地殻の断片(浅川沢花崗岩)も含んでいることが明らかになった．浅川沢花崗岩を形成した後期ジュラ紀火成活動は，古領家陸塊に起こったと考えられる．

＜地名＞
Aikawa----------------相川
Asakawazawa-------浅川沢
Atera Nanataki-----阿寺七滝
Mikawaono-----------三河大野
Nanasatoisshiki-----七郷一色
Ohshima---------------大島
Suyama----------------巣山
Toei---------------------東栄