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Studies on Granitic Pegmatites II

Magnesium and Iron Contents of Biotites of Small Size in Granites and Pegmatites

By

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Abstract

The writer has investigated the mafic contents in the biotites not only of the granites covering Hiéi, Gyoja-Yama, and Tanakami-Mikumo regions, but of the pegmatites embedded in the granite-stock of Tanakami-Mikumo, in order to make clear the following:

(1) The relation between the magnitude of mafic content of biotite and its crystallization stage, the biotite belonging to the granitic pegmatite of the druse type of Yuwane village.

(2) The statistical difference in mafic content of biotite between Hiéi and Gyoja-Yama granites; the former granite bearing plenty of allanite as an accessory ingredient and the latter bearing little.

(3) The characteristics of mafic contents in the biotites of the granite and pegmatite which contain plenty of allanite as an accessory ingredient.

And the conclusions drawn in regard to the above are as follows:

(1) In druse pegmatite an early-crystallized biotite contains more Mg than a late-crystallized one and the reverse with Fe content.

(2) There is a difference in Fe content in biotite of granite-stock between the two regions.

(3) In the area treated here, when both 'N' and 'F' of the biotite contained in granite or pegmatite are relatively large, plenty of allanite as accessory is certainly found in that rock. The above fact may suggest that, when both 'N' and 'F' of a granitic magma or a pegmatitic fluid were relatively large, plenty of allanite as accessory was crystallized out at the approximately same time as biotite, in the region treated here, considering not only from the origin of granite and pegmatite, the modes of the mineral components and the chemical compositions of those, but also from the crystallization stage of both biotite and allanite contained in those rocks.

Introduction

As a sequel to his previous paper[1], the writer treats in this paper of the characteristics of mafic content in biotite not only of Hiéi, Gyoja-Yama, Tanakami-Mikumo and Tango-Oku-Tango granites, but of Tanakami-Mikumo pegmatites, in the following order:

(1) The description of granite and pegmatite in Tanakami-Mikumo region, and the inquiry into mafic content in biotite contained in those rocks.
(2) The description of granite and pegmatite in Hiéi and Gyoja-Yama regions and the statistic inquiry into mafic content of biotite of both the regions.
(3) The inquiry into mafic content in biotite of the granite and pegmatite which contain plenty of allanite as accessory.

Especially, in regard to Clause 3, the origin of granite in these areas is first discussed; secondly the crystallization stages of both biotite and allanite contained in granite and pegmatite; then comparison is made between mafic content of biotite in paragenesis with plenty of allanite and that of biotite in paragenesis with little or no; and lastly, on the basis of the above results are discussed the characteristics of the mafic content of the biotite in paragenesis with plenty of allanite as accessory.

But, before entering upon the main subject, the writer will trace back petrological history and see how allanite has been studied as an accessory of both granite and granitic pegmatite.

It was in 1885 that P. IDDINGS and C. WHITMAN[2] paid attention to allanite as an accessory mineral of granite and dealt with it petrologically for the first time. They pointed out that it was as important an accessory mineral of rock as zircon, sphene, apatite and magnetite, enumerating a small number of allanite-bearing rocks and a very few localities where such rocks lay. But since then little notice had been taken of it till only in 1957 W.L. SMITH and his co-workers[3] discussed allanite and content of uranium & thorium in allanite-bearing rocks of five American localities.

On the other hand, it was H. BJØLYKKE[4] who first gave an eye to allanite as an accessory mineral of granitic pegmatite and dealt petrochemically with it. Later on, his study was followed in Japan by H. SHIBATA's research[5] of the similar kind regarding granitic pegmatite of Naegi region.

On mafic content in biotte of both granite and pegmatite in Tanakami-Mikumo region

In this region lies the granite-stock whose pegmatites* have long served many Japanese geologists as their objects of study, and have produced specimens of minerals of world-wide fame for their splendor (Fig. 1).

Now, as for the part of the granite-stock lying to the west of Mikumo, a number of studies have been made by I. HAYASE[6], T. ASAYAMA[7], Z. HATUDA, C. IN[8], and

* The pegmatites of Tanakami locality have been researched by T. OGAWA[11]; M. NAKATSUKASA[12]; S. KAWASAKI[13]; T. HATTORI, M. HIGAMI & M. SHIRAKAMI[14]; M. HIGAMI[15]; and J. TAKUBO & K. ŌYA[16]. According to these studies, the pegmatites there, being mostly druse pegmatites, produce quartz, feldspar, biotite, topaz, garnet, rutile, hübnerite, cassiterite, monazite, tourmaline, calcite, pyrite, beryl, molibdenite, galena, zincblende, pyrrhotite, zircon, gadolinite, manganese minerals, takizōseki, monazite (rinōseki), yttrotantalite etc., but there has been no record of allanite found from those pegmatites. Table 3, B shows chemical compositions of biotites in pegmatites of Tananami.

the present writer[1]. According to these studies, coarse-grained biotite-granite covers most of this locality, while hornblende is contained a little in the rock lying in Konze and its vicinity. Tanakami and its vicinity-granite whose mode and chemical composition are shown in Table 1 and 2, contains far less biotite than granite of Hiéi and Gyoja-Yama regions (Table 5, B). Among all the granites, that of Tachiki (the most western part of the granite-stock) contains various-coloured micas, as the writer fully described in his previous paper[1], while the others* contain generally identical-coloured biotite (its pleochroism: X···pale yellow, Z···dark brown); though biotite rarely combines with muscovite as in Fig. 2.

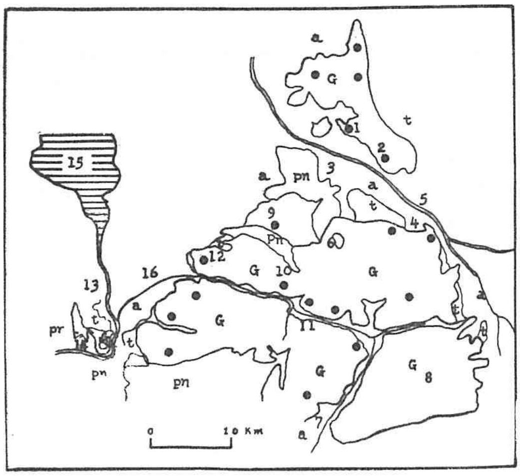

Fig. 1. Locations for samples and geological map of Tanakami-Mikumo Region, Shiga Prefecture.

1 Bodaiji, 2 Yuwane, 3 Ishibe, 4 Mikumo, 5 Yasu River, 6 Kannonji, 7 Shigaraki, 8 Yuwao-Yama, 9 Kiriu, 10 Konze-Dera, 11 Ōtorii, 12 Kami-Tanakami, 13 Seta River, 14 Tachiki, 15 Biwa Lake, 16 Ōdo River
●: Location for a sample, G: granite
a: alluvium, t: tertiary, pn: palaeozoic

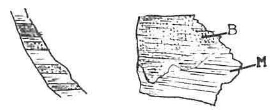

Fig. 2. Parallel growth of biotite and muscovite.
B: biotite M: muscovite

Yuwane village and its vicinity[9]:—The locality lying at the northeastern end of this granite-stock, is separated from Mikumo region by the Recent stratum developing along the drainage of the Yasu river running northwards. The granite of this locality is generally coarse-grained biotite-granite, while hornblende is contained a little in Yuwane and its vicinity. The pleochroism of biotite in the rock is as follows: X···pale yellowish brown and Z···blackish brown. Moreover, plenty of allanite is contained in the granite as accessory.

Table 1. The mode of granite of Tanakami and its vicinity

minerals	feldspars quartz	biotite	magnetite	chlorite	others
	97.7%	1.8%	0.1%	0.4%	0.0_1%

* Samples used in analyses belong to this kind, except those specially mentioned.

Table 2. Chemical compositions of granite samples of Tanakami-Mikumo, Hiéi and Gyoja-Yama regions[7].

comp.	Gyoja-Yama	Hiéi	Tanakami	Mikumo
SiO_2	72.16	72.75	73.96	72.88
TiO_2	0.35	0.21	0.13	0.22
Al_2O_3	13.93	14.38	14.12	14.31
FeO	0.49	0.64	0.52	0.65
Fe_2O_3	2.23	1.75	1.43	1.70
CaO	2.02	2.14	1.53	2.59
MgO	0.63	0.63	0.15	0.39
MnO	0.26	0.05	0.05	0.04
K_2O	3.23	2.86	3.99	3.61
Na_2O	3.61	3.89	3.66	3.17
H_2O^+	0.81	0.70	0.46	0.44
P_2O_5	0.28	—	—	—
total	100.00	100.00	100.00	100.00
$\frac{Mg}{Fe^{\cdot\cdot}+Fe^{\cdot\cdot\cdot}}$	$\frac{0.38}{2.08}$	$\frac{0.38}{1.81}$	$\frac{0.09}{1.47}$	$\frac{0.24}{1.78}$
number of analy. samp.	1	14	13	9

Average of 14 granite samples from the Hiéi region.
Average of 13 granite samples from the Tanakami region.
Average of 9 granite samples from the Mikumo region.

Table 3, A. Mg and Fe contents in biotites of granite and pegmatite from the Hanazono and Bodaiji region.

locality	occurrence		Mg %	Fe %	Mg †	Fe †	N	F
Hanazono	nearby granite		2.46	22.05	1.0	4.0	5.0	0.80
	pegmatite I	1st zone	3.30	26.04	1.4	4.7	6.1	0.77
		2nd zone	3.13	25.97	1.3	4.7	6.0	0.78
		3rd zone	2.82	26.74	1.2	4.8	6.0	0.80
		the most inner zone	1.62	27.86	0.7	5.0	5.7	0.88
	pegmatite II	1st zone	2.82	24.29	1.2	4.4	5.6	0.79
		3rd zone	0.78	26.60	0.3	4.8	5.1	0.94
	pegmatite III	1st zone	2.94	24.50	1.2	4.4	5.6	0.79
Bodaiji	nearby granite		1.62	23.45	0.7	4.2	4.9	0.86
	the most inner zone of pegmatite		0.78	25.76	0.3	4.6	4.9	0.94

† milligram atom/ gram for Mg and Fe respectively.

Table 3, B. Mg and Fe contents in biotites of pegmatite from the Tanakami region.

sample no.	I	II	III	IV
analyst	Geol. Sur. Jap.	do.	do.	do.
Mg %	0.20	0.21	0.39	0.25
Fe %	14.60	17.92	22.67	22.79
Mg †	0.1	0.1	0.2	0.1
Fe †	2.6	3.2	4.1	4.1
N	2.7	3.3	4.3	4.2
F	0.96	0.97	0.95	0.98

† milligram atom/gram for Mg and Fe respectively.

A. The pegmatite of Yuwane Village, Shiga Prefecture

Some years ago T. HATTORI[10] reported about the pegmatite of this locality, but the present writer deals especially with the pegmatites of the following two quarries :—

One which has lately been established by Yoshimura stone Mining Co., Inc., and is situated on the southern slope of 300 meters high mountain about 700 meters northeast of Hanazono. The other belonging to the Ōmi Stone Mining Co., Inc., and situated on the eastern slope of the peak line running north from the summit of a 353.3 meters high mountain about 1000 meters west of Bodaiji.

Any of the pegmatites embedded in the granites of the above two quarries, being of druse type, has an irregularly cucumber-shaped body with its length ranging from 10 centimetres to 2 meters. In the Fig. 3 is shown the most typical one which consists of the following four zones in the order from outside to inside.

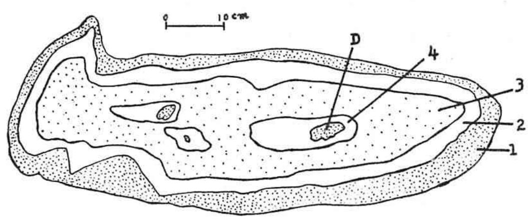

Fig. 3. Sketch of a druse pegmatite of Hanazono region.

1: 1st zone, 2: 2nd zone, 3: 3rd zone, 4: 4th zone, D: druse

1) The 1st zone consists of the medium-grained hornblende-bearing biotite granite which is rich in biotite; that is, it is composed principally of Plagioclase (mostly normal- or oscillatory-zoned oligoclase, the margin or a part of which changes often into myrmekite), perthite, orthoclase and biotite (its pleochroism: X···pale yellowish

brown, Z···dark blackish-brown), with common hornblende, allanite, apatite and magnetite as accessory ingredients.

2) The 2nd zone consists of the fine-grained graphic granite which is composed principally of quartz and perthite, with biotite and allanite as accessory ingredients.

3) The 3rd zone consists of the coarse-grained graphic granite which is composed principally of quartz and perthite, with plagioclase (euhedral crystal of small size) and biotite of large size (its pleochroism is just the same as that of the 1st zone), as accessory ingredients.

4) The 4th zone is mainly composed of the large-sized pale blue albite crystals surrounding the druse in which there is a gregarious growth of euhedral crystals of desmine.

Let us consider through what process such druse pegmatite was formed, from the viewpoint of its structure and the mode of the mineral paragenesis. When granitic magma*, by the consolidation of which nearby granite of pegmatite had been produced, solidified with the loss of heat, there came to appear several spots where volatile matter abounded; in other words, pegmatitic fluids** appeared in several spots. Then, each pegmatitic fluid commenced to consolidate from its outside which made contact with solidified wall granite as the temperature fell lower. What is noticeable in this case is that, as soon as such numerous crystal embryos of mafic minerals as biotite, hornblende, allanite, etc. came out, those embryos rapidly developed, because pegmatitic fluid was rich in volatile matter and consequently transfer velocity of ion was great. And the result was that most of mafic components in pegmatitic fluids took part in the creation of the above-mentioned minerals of the 1st zone. It was in the next process that the second, third and fourth zones came out in succession. In this stage of growth, the more inner the zone was, the far denser became the concentration of volatile matter in the fluid so that transfer velocity*** of ion might become greater. That may be one of the most important reasons why the largest crystal is found in the inmost zone****.

* On the granitic magma H. H. READ[17] says as follows: "If this magma, either as an open or closed system, had the proper composition, it would give rise on consolidation to a granite (as defined), and we may call such a magma the granitic magma." The present writer has the same opinion as he.

** From the definition of F. F. GROUT we may safely give the name of pegmatitic magma to the fluid from which pegmatite grew, but the writer thinks the term of pegmatitic fluid to be more general and therefore adopts it in the present paper as well as in the previous.

*** The decrease of transfer velocity of ion owing to the fall of the temperature of the fluid must of course be considered, but it seems that far greater than this is the increase of transfer velocity of ion owing to the rise of concentration of volatile matter.

**** The more outer the zone is, the smaller do the crystals get in size, not only because the concentration of volatile matter in pegmatitic fluid on the crystallization stage of the outer zone is smaller than that on the crystallization stage of the inner zone, but also because the falling velocity of temperature on the crystallizing stage of the outer zone is faster.

The components of the fluid also gradually varied and allowed a great amount of albite to crystallize out in the inmost zone, and it followed that euhedral crystals of desmine, quartz, etc. crystallized out in the inside druse, till at last the still remaining so-called hydrothermal solution acted upon the already-crystallized mica and feldspar so much that secondary minerals such as chlorite, sericite, etc. were created.

The writer has collected specimens of biotites from every zone of the pegmatite which has such structure and mechanism of producing as the above, and also from its nearby granite.

According to Table 3, A. the biotite of the first zone has larger mafic content (especially content of Fe far larger) than the biotite of the nearby granite and it is plain that Mg decreases and Fe increases in the order of the second, third and fourth zones; that is to say, in druse pegmatite, early-crystallized biotite contains more Mg than later crystallized one and vice versa with Fe. By the way, in this pegmatite any other mafic mineral is far smaller in its quantity than biotite; therefore the above-mentioned evidence means that Fe/Mg increased as pegmatitic fluid got into later stages.

B. The contents of Mg and Fe in the biotite of granite covering Tanakami-Mikumo region.

Analyzed samples were collected as randomly as possible from all over the granite-stock as shown in Fig. 1 and the analytical results of their mafic contents are shown in Table 4. From Table 4 and Table 6, it is clear that Mg contents of biotites in the granite are far smaller than those of biotites of both Hiéi and Gyoja-Yama granite-stocks.

Table 4. Mg and Fe contents in biotites of granite specimens from the Tanakami-Mikumo region.

sample no.	Mg %	Fe %	Mg †	Fe †	N	F
Hanazono	2.46	22.05	1.0	4.0	5.0	0.80
K-H 2	2.34	19.53	1.0	3.5	4.5	0.78
K-H 3	2.10	18.34	0.9	3.3	4.2	0.79
K-H 4	1.02	19.81	0.4	3.6	4.0	0.90
Bodaiji	1.62	23.45	0.7	4.2	4.9	0.86
M 1	1.50	21.91	0.6	3.9	4.5	0.87
M 3	1.26	18.20	0.5	3.3	3.8	0.87
M 4	1.38	18.55	0.6	3.3	3.9	0.85
Minaguchi 9	1.20	21.56	0.5	3.9	4.4	0.89
do. 4	1.08	14.07	0.4	2.5	2.9	0.86
do. 4″	0.90	20.65	0.4	3.7	4.1	0.90
do. 1	0.60	16.94	0.3	3.0	3.3	0.91
do. 2	0.72	14.07	0.3	2.5	2.8	0.89
Seta 1	1.08	19.95	0.4	3.6	4.0	0.90

(continued) Table 4.

sample no.	Mg %	Fe %	Mg †	Fe †	N	F
Seta 2	1.68	21.49	0.7	3.9	4.6	0.85
do. 3	2.22	25.41	0.9	4.6	5.5	0.84
do. 4	0.07	19.32	0.0_3	3.5	3.5_3	0.99
Tanakami 3	0.34	16.24	0.1	2.9	3.0	0.97
Tachiki 70‡	0.86	19.60	0.4	3.5	3.9	0.90
do. 11‡	0.09	18.55	0.0_4	3.3	3.3_4	0.99
do. 11‡	0.23	20.16	0.1	3.6	3.7	0.97
do. 11‡	0.14	21.35	0.1	3.8	3.9	0.97
do. 65‡	0.16	16.45	0.1	3.0	3.1	0.97
do. 65‡	0.15	13.09	0.1	2.3	2.4	0.96

† milligram atom/gram for Mg and Fe respectively.
‡ The writer's previous paper[1].

The statistical comparison between the mafic contents of the biotites of Hiéi granite and those of Gyoja-Yama granite.

The granite-stock of Gyoja-Yama has been studied by T. UEDA[19], Awamura Mining Co.[20] Inc.; I. HAYASE & T.TSUTSUMI[21]; J. HATUDA & C. IN[8]; and the writer[1]; and the pegmatite of the same area has been investigated by Awamura Mining Co. Inc.[20]. The granite-stock of Hiéi has been studied by D. YAMASHITA[22], S. NAKAMURA[23], T. HIKI[24], T. ASAYAMA[25], H. SHIBATA[26], H. ITO[27], and the writer[1], while J. TAKUBO[28], T. HIGAMI[29], etc. have studied the pegmatites of the same region.

According to these studies, the distance between the granite-stocks of Hiéi and Gyoja-Yama is no more than about 20 kilo-metres; and any of the granites of the two regions is the granite-stock intruding in the palaeozoic strata and has 10 square kilo-metres outcropping area. The comparison between the granites of the two localities is shown in Table 5. As the table plainly shows, it is hardly possible to find any remarkable difference between these two granites in point of chemical as well as mineral components, except that the granite of Hiéi region contains plenty of allanite as accessory, while Gyoja-Yama granite contains little*, and generally speaking, any of those granite-stocks has homogeneous rock facies**.

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* The writer investigated about 100 thin sections of Gyoja-Yama granite, but could not find any allanite,

** Comparing pegmatites of these two localities, we find that in the pegmatite of Gyoja-Yama there occur scheelite, pyrite, chalcopyrite, zincblende, pyrrhotite, cassiterite arsenopyrite, but there has been no record of allanite occurrence, while pegmatite of Hiéi usually contains allanite.

Table 5, A. Characteristic of component minerals of Hiéi-granite and Gyoja-Yama granite.

locarity	plagioclase	alkali-feldspar	biotite	accessory minerals	myrmekite
Hiéi	°mostly oligoclase °common zonal and oscillatory zonal	°large, anhedral perthite °subhedral microcline °subhedral orthoclase	°plaeochroism : X…pale brown Y…brown Z…dark brown °2V : small	°magnetite °sphene °apatite °hornblende (rare) °chlorite °allanite °zircon	existence
Gyoja-Yama	do.	do.	do.	°magnetite °sphene °apatite °chlorite °monazite °zircon	do.

Table 5, B. Modes of granites from the above two regions.

locality	feldspars & quartz	biotite	magnetite	chlorite	others
Gyoja-Yama	89.7	8.3	0.2	1.6	0.2
Hiéi	91.8	6.1	0.2	1.7	0.2

Thus it may be allowed to investigate statistically mafic content in biotite of the granite-stocks, according to the following reasons:

(1) Each of both granite-stocks has generally a homogeneous rock facies.

(2) The outcropping area of Hiéi granite-stock is nearly equal to that of Gyoja-Yama granite-stock.

Now, biotite samples were collected as randomly as possible from all over the outcrop of each of the two granite-stocks, as shown in Fig. 4 and Fig. 1, C in the previous paper, and accordingly it is possible to regard that the analytical results of those biotites (Table 6, A, B) show features of mafic content in biotite of each granite-stock.

The analytical results were investigated

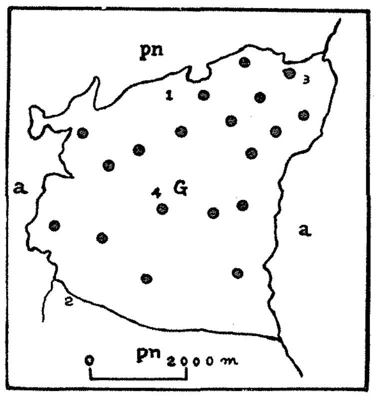

Fig. 4. Locations of Hiéi gtanite samples.

1 Shimegadake, 2 Daimonji, 3 Sakamoto, 4 Yamanaka

statistically by means of a process[44] (to be described elsewhere) to learn whether there should be any difference between the granites of the two regions in mafic content in biotite and the writer has reached the following conclusions:

We can clearly say there is a difference between the granites of the two regions in the mean value of Fe content in biotite, but it is difficult to assert that there is a difference in that of Mg content.

Table 6. Mg and Fe contents in biotites of granite specimens from the Hiéi and Gyoja-Yama regions.

A. Hiéi region

sample no.	Mg %	Fe %	Mg †	Fe †	N	F
88′	6.12	19.36	2.5	3.5	6.0	0.58
13′	4.32	22.30	1.8	4.0	5.8	0.69
6	5.58	22.05	2.3	4.0	6.3	0.64
50	5.94	19.95	2.4	3.6	6.0	0.60
17	5.28	18.90	2.2	3.4	5.6	0.61
18	4.44	17.50	1.8	3.1	4.9	0.63
57	6.00	20.16	2.5	3.6	6.1	0.59
60	5.70	22.05	2.3	4.0	6.3	0.64
65	5.40	22.40	2.2	4.0	6.2	0.65
66	5.04	19.25	2.1	3.5	5.6	0.63
67	5.28	19.60	2.2	3.5	5.7	0.61
20	5.80	21.60	2.4	3.9	6.3	0.62
23	6.66	19.81	2.7	3.6	6.3	0.57
24	4.62	17.50	1.9	3.1	5.0	0.62
25	5.40	20.44	2.2	3.7	5.9	0.63
30	5.50	22.10	2.3	4.0	6.3	0.64
37	5.80	21.41	2.4	3.8	6.2	0.61
41	4.20	20.93	1.7	3.8	5.5	0.69
44	6.10	20.20	2.5	3.7	6.2	0.60
mean value	5.43	20.40	2.2	3.7	5.9	0.62
no. of anal. samp. 19						

B. Gyoja-Yama region

sample no.	Mg %	Fe %	Mg †	Fe †	N	F
Ts. 43, 1	6.12	16.10	2.5	2.9	5.4	0.54
Ts. 46	5.22	16.80	2.2	3.0	5.2	0.58
Bka 2	6.30	13.02	2.6	2.3	4.9	0.47
Bka 3	6.18	16.45	2.6	2.9	5.5	0.53
Bka 3L	6.90	17.15	2.8	3.1	5.9	0.53
8	6.42	19.60	2.6	3.5	6.1	0.57
13	7.14	16.59	2.9	3.0	5.9	0.51
Yun.	6.12	14.70	2.5	2.6	5.1	0.51
97	7.62	16.80	3.1	3.0	6.1	0.49
38	7.08	15.96	2.9	2.9	5.8	0.50
57	5.58	15.61	2.3	2.8	5.1	0.55
88	4.14	19.25	1.7	3.5	5.2	0.67
6	6.12	16.17	2.5	2.9	5.4	0.54
6 bn	6.36	16.45	2.6	2.9	5.5	0.53
6L	5.88	17.50	2.4	3.1	5.5	0.56
33	7.08	19.81	2.9	3.6	6.5	0.55
76	4.44	14.35	1.8	2.6	4.4	0.59
71	5.04	18.27	2.1	3.3	5.4	0.61
4	6.54	15.47	2.7	2.8	5.5	0.51
9	6.66	13.93	2.7	2.5	5.2	0.48
17	5.28	16.10	2.2	2.9	5.1	0.57
27	4.92	15.82	2.0	2.8	4.8	0.58
52	5.16	16.66	2.1	3.0	5.1	0.59
69	6.12	16.87	2.5	3.0	5.5	0.55
75	6.78	18.27	2.8	3.3	6.1	0.54
35	5.16	20.30	2.1	3.6	5.7	0.63
65	5.16	17.50	2.1	3.1	5.2	0.60
65	4.38	16.66	1.8	3.0	4.8	0.63
68	6.18	15.96	2.6	2.9	5.5	0.53
70	5.34	15.47	2.2	2.8	5.0	0.56
mean value	5.91	16.66	2.4	3.0	5.4	0.55
no. of anal. samp. 30						

† milligram atom/gram for Mg and Fe respectively.

Procedure:

1. Comparison between granites of Hiéi and Gyoja-Yama in mean value of Fe content in biotite.

a. Test of population variances (Table 6, A, B)

Calculating F and making the test:

$$n_1 = 19 \qquad n_1 s_1^2 = 41.8$$
$$n_2 = 30 \qquad n_2 s_2^2 = 79.5$$

where n_1 and n_2 are respectively the numbers of analytical samples from the Hiéi and Gyoja-Yama granite-stocks; and s_1 and s_2 are respectively the sample variances of Fe contents in the biotites of the two granite-stocks.

$$\frac{\frac{1}{n_2-1} n_2 s_2^2}{\frac{1}{n_1-1} n_1 s_1^2} = 1.18$$

The critical values for F, 30, 18 D.F. are:

5 per cent 2.11 1 per cent 2.91

The critical value for F, 29, 18 D.F. can not be found in the table of F-distribntion but that value should be less than the above, and consequently the value found for F is smaller than the critical 1 per cent value for F, 29, 18 D.F..

Hence we can not reject the assumption that the population variance of Fe contents in the biotites of the Hiéi granite-stock is equal to that of the Gyoja-Yama granite-stock.

b. Test of mean values

Calculating t and making the test:

$$\bar{x} = 20.40 \qquad \bar{y} = 16.66$$

where $\bar{x}$ and $\bar{y}$ are respectively the sample means of Fe contents in the biotites of Hiéi and Gyoja-Yama granite-stocks.

$$\sqrt{\frac{n_1 n_2 (n_1+n_2-2)}{n_1+n_2}} \frac{|\bar{x}-\bar{y}|}{\sqrt{n_1 s_1^2 + n_2 s_2^1}} = 7.945$$

The critical value for t, 45 D.F. is:

1 per cent 2.690

The critical value for t 47 D.F. can not be found in the table of t-distribution but that value should be less than the above, and consequently the value for t is much larger than the critical 1 per cent value for t, 47 D.F..

Hence, the conclusion is that there is a difference between Hiéi and Gyoja-Yama granite-stocks in the population mean of Fe content in biotite.

2. Comparison between granite-stocks of Hiéi and Gyoja-Yama in mean value of Mg content in biotite.

a. Test of population variances

Calculating F and making the test:

$$n_1 = 19 \qquad n_1 s_1^2 = 7.8$$
$$n_2 = 30 \qquad n_2 s_2^2 = 23.5$$

where n_1 and n_2 are respectively the numbers of analytical samples from the Hiéi and Gyoja-Yama granite-stocks; and s_1 and s_2 are respectively the sample variances of Mg contents in the biotites of the two granite-stocks.

$$\frac{\frac{1}{n_2-1} n_2 s_2^2}{\frac{1}{n_1-1} n_1 s_1^2} = 1.88$$

The critical values for F, 30, 18 D.F. are:

5 per cent 2.11 1 per cent 2.91

The critical value for F, 29, 18 D.F. can not be found in the table of F-distribution, but that value should be less than the above, and consequently the value found for F is smaller than the critical 1 per cent value for F, 29, 18 D.F..

Hence we can not reject the assumption that the population variance of Mg content in biotite of Hiéi granite-stock is equal to that of Gyoja-Yama granite-stock.

b. Test of mean values

Calculating t and making the test:

$$\bar{x} = 5.43 \qquad \bar{y} = 5.91$$

where $\bar{x}$ and $\bar{y}$ are respectively the sample means of Mg contents in the biotites of the Hiéi and Gyoja-Yama granite-stocks.

$$\sqrt{\frac{n_1 n_2 (n_1+n_2-2)}{n_1+n_2}} \cdot \frac{|\bar{x}-\bar{y}|}{\sqrt{n_1 s_1^2 + n_1 s_2^2}} = 2.005$$

The critical value for t, 50 D.F. is:

5 per cent 2.008 1 per cent 2.678

The critical value for t, 47 D.F. can not be found in the table of t-distribution, but that value should be larger than the above, and consequently the value found for t is smaller than the critical 1 per cent value for t, 47 D.F..

Hence we can not reject the assumption that the population mean of Mg content in biotite of Hiéi granite-stock is equal to that of Gyoja-Yama granite-stock.

On Fe and Mg contents in biotite of the granite and pegmatite which contain plenty of allanite as an accessory ingredient.

A. The origin not only of the granites of the regions treated in this paper (including Tango and Oku-Tango regions) but also of the pegmatites of Yuwane.

The writer considers all the granites of these localites were produced by the consolidation of granitic magma*, as they have all the following evidences by which F.F. GROUT[18], G.E. GOODSPEED[30] and N.L. BOWEN[31] discern a rock body which grew out of a magma.

(1) Sharp contact with country rock.

(a) The Tango-Oku-Tango granite makes sharp contact with the Palaeozoic in the southern part of the area, and it gave metamorphic effect to Yakuno intrusive rocks.[32]

(b) The Gyoja-Yama granite mades sharp contact with the surrounding Palaeozoic, and the Hiéi granite also makes sharp contact with the Palaeozoic at Mt. Hiéi and Mt. Daimonji, and those granites gave metamorphic effect to rocks of the Palaeozoic**.

(c) The Tanakami-Mikumo granite makes sharp contact with the Palaeozoic in the regions of Tachiki, Tanakami and Konze etc., while the roof-pendant of the Palaeozoic still remains near Ōtorii and Kannonji, etc.

(2) Chemical composition is distinctly uniform throughout an area in such a small rock body as the granite-stock of Hiéi.[7]

(3) Petrographic criteria

(a) In such small rock bodies as those of Hiéi and Gyoja-Yama, a texture of a rock is generally uniform throughout an area.

(b) That all minerals, especially earlier-formed ones, are usually subhedral with sharp boundaries, is evidently true with granite of any region.

(c) It is noticeable in any region that a thin section of rock of contact zone usually shows a clear demarcation between the material of the granite body and that of its surroundings.

(d) In any region, xenoliths show reaction effect of either the early magmatic or late deuteric stage of crystallization.

(e) A granite of any region has a feature that its plagioclase shows a conspicuous zonal structure, especially of an oscillatory type.

As for the origin of pegmatites of Yuwane region, see the foregoing paragraph.

B. On the crystallization stage of both biotite and allanite contained in granite and pegmatite

As for the crystallization stage of accessory minerals in igneous rocks there are generally three different views, of which we have no established theory:

One of them is called the Rosenbusch's Rule of crystallization in igneous rocks,

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* The writer thinks that it was the magma that produced the present outcropping granite as a result of erosion, but the question that through what process this magma came into existence—namely either through differentiation of basaltic magma as N. L. Bowen said, or through the refusion of sialic substances or sedimentary rocks under geosyncline, is out of the writer's discussion.

** A number of contact minerals, such as cordierite and wollastonite, are found in the Palaeozoic.

being advocated by F.H. HATCH & A.D. WELLS[33]; K. RANKAMA & T.G. SAHAMA[34]; E.E. WHAHLSTROM[35]; H. WILLIAMS, F.J. TURNER & C.M. GILBERT[36]; L.T.G. SCHERMERHORN[37]; etc.. The view is best epitomized by the following description by F.H. HATCH & A.K. WELLS: "The commonly observed sequence was found to be: accessory minerals, ferro-magnesian minerals, feldspars, quartz··· However, many exceptions have been observed, and the principle is liable to misinterpretation since the observed order is that of the completion, but not the commencement of crystallization".

The second view may be best represented by S.J. SHAND's statement[38]: "It will be seen that the very first section* of the rule appears to contradict the laws of solution, for the components that are present in least amount ought to be among the last to crystallize". Of late W.W. MOORHOUSE[39] supports this view.

The exponent of the third view is W.T. SCHALLER[40] who implied that: "The accessory minerals and other hydrous (!) minerals such as hornblende and micas, for example, in a granite are not original pyrogenic minerals formed directly from magma but are later reaction product in an already formed rock···"

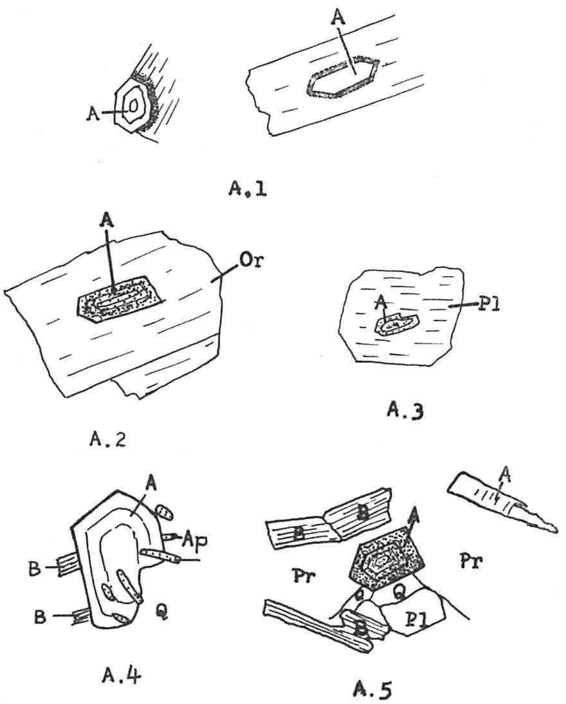

Fig. 5, A. Mode of occurrence of allanites in granites.
A, 1 Allanite in biotite (Hiéi 17, Hanazono G.)
A, 2 Allanite in orthoclase (Hanazono)
A, 3 Allanite in plagioclase (Hanazono)
A, 4 Allanite in quartz (Hiéi 23)
A, 5 Allanite in perthite (Hiéi 23)
A allanite, B biotite, O orthoclase, Pl Plagioclase
Q quartz, Ap apatite, Pr Perthite

The present writer, observing the mode of occurrence of allanite in the granites

* The very first section of the rule is that of the Rosenbusch Rule; in other words, the completion of crystallization of accessory minerals (such as zircon, xenotime, apatite, magnetite, chromite, sphene: or more generally those constituents which are present in the smallest quantity) is earlier than that of all other minerals in eruptive rocks.

and the pegmatites of the regions treated in this and his previous papers, came to the following conclusion.

(1) A crystal of allanite very often shows a predominant zonal structure (Fig. 5, A, B).

This evidence signifies that the composition of its mother fluid underwent a remarkable change continuously from the beginning of allanite crystallization till the completion of its growth.

(2) It not seldom happens that allanite is found as a fine euhedral crystal (Fig. 5, A).

This evidence may be interpreted in two ways: one interpretation attributes the above fact to the strong crystallizing power of allanite, while the other regards it as an evidence that allanite is a mineral that crystallized out at an earlier stage, according to the rule that earlier crystals are generally well shaped, whereas later ones are less so owing to their mutual interference.

(3) Allanite sometimes occurs as a mineral of an irregular figure (Fig. 5, A 5, B 1, B 2).

This evidence may also be interpreted in two ways: one is that allanite has come to take such a figure because it was corroded by residual fluid after it had crystallized out in the shape of euhedral. The other is that the irregularity of the figure is due to the result that allanite was hindered from growing by the obstructive faces of already formed minerals, because it crystallized out of residual fluid in the interstitial spaces among the minerals which had already crystallized.

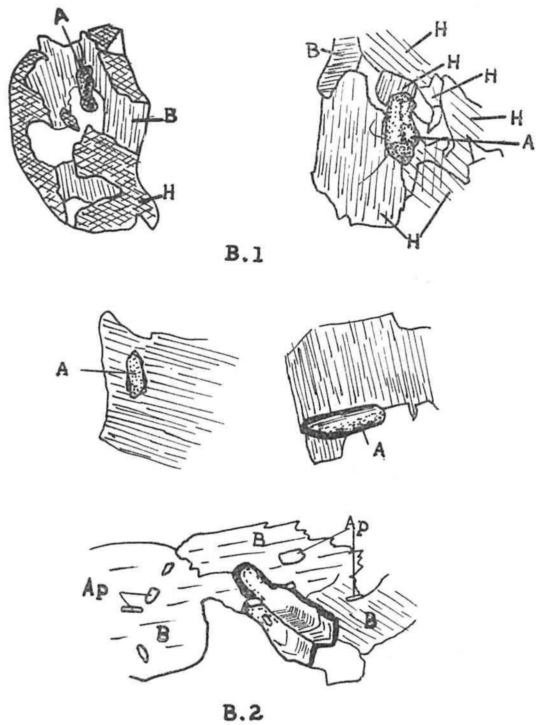

Fig. 5. B. Mode of occurrence of allanites in granites.

B, 1 Paragenetic relations among allanites, hornblendes and biotites. (Hanazono)

B, 2 Allanites included in biotites, (Hanazono, Hiéi 24)

A allanite, H hornblende, B biotite, Ap apatite

(4) Allanite is often included in most principal minerals of granite in such a mode as is shown in Fig. 5, A, B.

The above evidence may reasonably be interpreted that the completion of allanite was earlier than that of principal minerals of granite (biotite, orthoclase, plagioclase, perthite and quartz), according to the rule that when one crystal encloses another the latter is of earlier formation. But, in case that allanite is included in a mineral with a clear cleavage such as biotite, orthoclase, plagioclase, etc., the direction of the longer axis (b-axis) of allanite is very frequently almost parallel to the cleavage. This fact, we may understand, shows that, on crystallizing out of the residual solution of its mother fluid and on replacing already formed minerals, allanite grew up more abundantly in the direction where binding power was weaker in the structure of host minerals and replacement easier.

(5) Allanite very often lies on or just within the margin of a principal rock-forming mineral (Fig. 5, A, B 1, 2).

This evidence may mean that allanite did not crystallize out earlier than principal rock-forming minerals, according to the rule described in (4); whereas, if L.T.G. SCHERMERHORN's opinion* is applicable to allanite in granite, the above evidence may also be considered showing that allanite was of an earlier crystallization than principal rock-forming minerals.

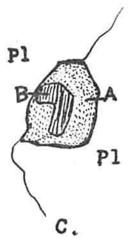

Fig. 5, C. Allanite including a biotite.
Pl plagioclase, A allanite, B biotite

(6) Allanite often includes plagioclase,, biotite, etc.. (Fig. 5 C)

Of the above-mentioned evidences, (6) points out that with nothing more than (2) and (4) we cannot rightly jump to the conclution that allanite crystallized earlier than any other component of granite; moreover (1), (3) and (5) do not serve as positive proofs that crystallization of allanite belongs to an earlier or later stage.

Thus, so far as the evidences that the writer got out of his observation are concerned, there are no conclusive data that decide the stage of allanite crystallization. Such being the case, the writer cannot approve any of the three foregoing views about the crystallization stage of accessory minerals in igneous rocks.

What the writer needs, however, in the process of his discussion, is not the decision of the absolute crystallization stage of allanite, but the relation between the crystallization stage of allanite and that of biotite in granite. Now, as for this point, researchers** who maintain the view that primary accessory minerals in granite

* "Zircon and other primary accessories crystallize early and move about in the magma... Most of the separated primary accessories came into contact with growing biotite, to be enclosed by it".

** P. IDDINGS & C. WHITMANN clearly points out that allanite crystallized out at the apporoximately same stage as zircon, sphene, apatite etc.: "In one instance it was noticed enclosing zircon; in others, sphene, apatite and magnetite, but it has been found in such connection with these minerals as to indicate a contemporaneous growth. Its nature as a primary constituent in eruptive rocks is further attested by its occasional inclusion in biotite, feldspar and quartz".

crystallized out in the early stage, think that the completion of crystallization of primary accessory minerals took place in the earliest stage, immediately followed by that of biotite. Though MOORHOUSE[39] as well as SHAND[38] does not express his definite opinion, he points out statistically that primary accessory minerals are preferentially distributed or concentrated in biotite or hornblende so far as granite is concerned. SCHALLER[40] thinks that both the minerals crystallized out in the same deuteric stage.

Considering from the facts that (1) allanite and biotite interlock each other, that (2) euhedral allanite is included in biotite, while the latter is sometimes included

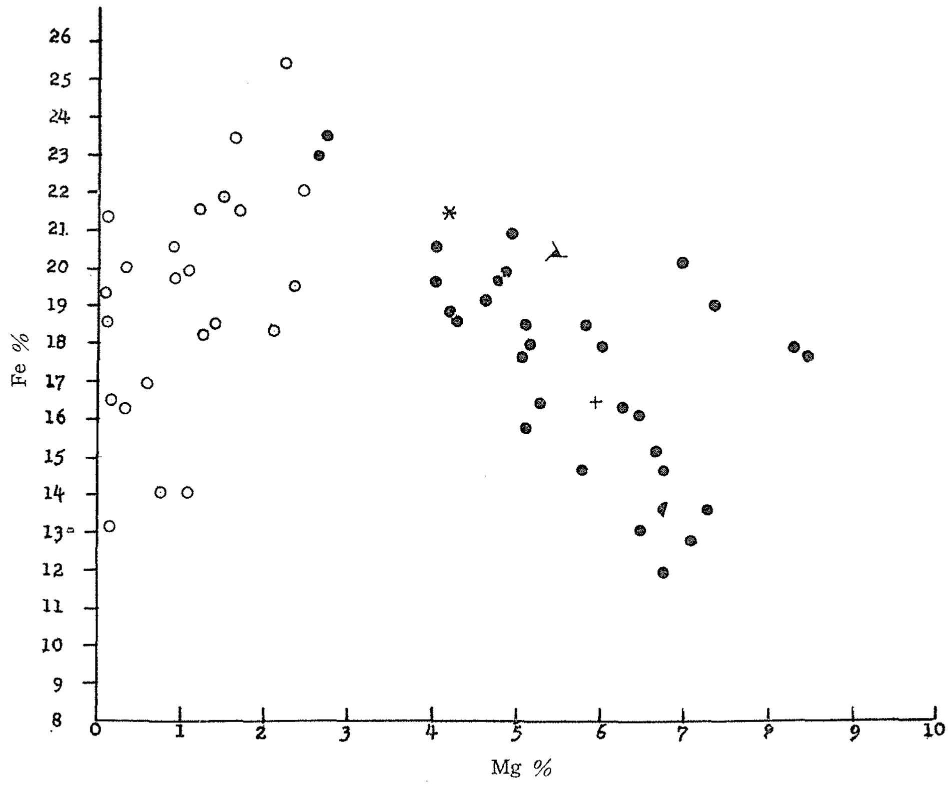

Fig. 6. Correlation diagram of Mg and Fe weight percentages in biotites.

● A biotite of a granite specimen from Tango and Oku-Tango district
○ A biotite of a granite specimen from Tanakami-Mikumo region
+ The mean values of Mg ann Fe percentages in biotites of granite specimens from Gyoja-Yama region
▲ The mean values of Mg and Fe percentages in biotites of granite specimens from Hiéi region
✳ The mean values of Mg and Fe percentages in biotite of granite specimens from Yura and Kunda district

in the former; the writer thinks that both the minerals grew up contemporaneously and that it cannot be unconditionally decided, which was earlier or later in commencing and completing its crystallization.

C. Comparison in mafic content between biotite in paragenesis with plenty of allanite, and biotite in paragenesis with little or no.

(1) Biotite of granite

Plotting Fe % against Mg %, we get Fig. 6; and also plotting "F" against "N", we get Fig. 7, where "N" is the sum of milligram atom/gram for Mg and that for Fe, and where milligram atom/gram for Fe divided by "N" gives "F".

From Fig. 7, it is quite evident that "N" of biotite in paragenesis with plenty of allanite is generally larger than "N" of that with little or no.

As for the difference between mafic content in biotite of Hiéi granite (bearing

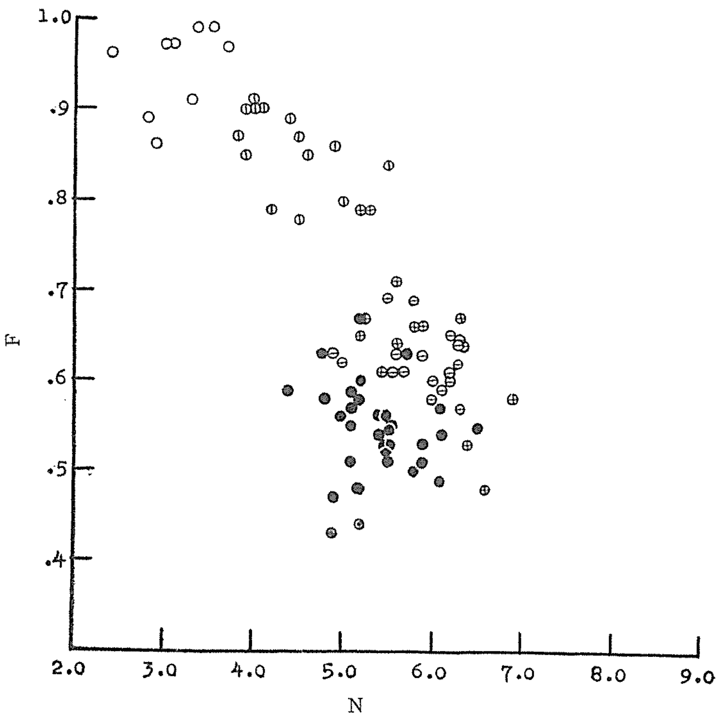

Fig. 7. Correlation diagram of F and N in biotites.

○ A biotites of granite specimen containing no allanite from Tanakami-Mikumo region
⦶ A biotite of a granite specimen containing allanite from Tanakami-Mikumo region
⊖ A biotite of a granite specimen from Hiéi region
● A biotite of a granite specimen from Gyoja-Yama region
⊕ A biotite of a granite specimen containing allanite from Tango and Oku-Tango region
⊙ A biotite of a nearby granite of the Ōro pegmatite, not in paragenesis with allanite

plenty of allanite as accessory) and that of Gyoja-Yama (bearing little allanite), see the foregoing paragraph.

(2) Pegmatite of Tanakami-Mikumo region.

The writer has dwelt upon it in the foregoing paragraph, stating that plenty of allanite is produced out of pegmatite in Yuwane Village and its neighbourhood, but no allanite has been found in pegmatite of Tanakami, though many an investigation has been made up to date.

Table 3 A and B were made for the purpose of comparing mafic content in biotite of pegmatites of the two regions. The Table clearly shows that "N" of the biotite of the Yuwane-pegmatite is larger than "N" of the Tanakami one.

Table 7. Mg and Fe contents in biotites of granite from the Tango and Oku-Tango region.

sample no.	Mg %	Fe %	Mg †	Fe †	N	F	locality and note
BG 1	6.72	11.83	2.8	2.1	4.9	0.43	nearby granite of the Ōro pegmatite, with no allanite
BH 1	7.08	12.88	2.9	2.3	5.2	0.44	Masudome, with no allanite
B 14	7.32	19.04	3.0	3.4	6.4	0.53	the nearby granite of the Mié pegmatite with allanite
B 11	8.28	18.06	3.4	3.2	6.6	0.48	the nearby granite of the Kōbe pegmatite with allanite
55	2.58	23.00	1.1	4.1	5.2	0.79	the nearby granite of the Kawakami pegmatite with allanite
56	2.70	23.54	1.1	4.2	5.3	0.79	do.
BM 2	6.96	22.12	2.9	4.0	6.9	0.58	Mié, with allanite
B 30b	4.92	20.95	2.0	3.8	5.8	0.66	Chōzen, with allanite
Tan. 7	3.84	22.05	1.6	4.0	5.6	0.71	Kunda, with allanite
Tan. 12	5.10	23.45	2.1	4.2	6.3	0.67	Yura, with allanite
BYS	4.86	21.70	2.0	3.9	5.9	0.66	do., with allanite
Toy. 4 ‡	5.10	18.55	2.1	3.3	5.4	0.61	Okuyane, Toyooka dist., with allanite
Toy. 4′ ‡	4.86	19.95	2.0	3.6	5.6	0.64	do.
Taki 2, 4‡	4.02	19.60	1.7	3.5	5.2	0.67	Taki, with allanite
Taki 5, 6‡	4.26	18.69	1.8	3.4	5.2	0.65	Oku-Taki, with allanite
Taki 15 ‡	5.28	16.45	2.2	3.0	5.2	0.58	Kumohara, Amada Dist.
Fuku. 2″‡	6.48	13.09	2.7	2.3	5.0	0.46	Kami-Sasaki, Amada Dist.
Onari 1 ‡	6.66	15.19	2.7	2.7	5.4	0.50	Onari, Mineyama Town. Hornblende biotite granite
Onari 2 ‡	6.24	16.31	2.6	2.9	5.5	0.53	do.

‡ New analytical results added. after the previous paper had been announced.
† milligram atom/gram for Mg and Fe respectively.

D. Discussion.

Before entering upon the discussion, the paragraph A and C may be summed up as follows:

(1) The granites of the regions mentioned here, were produced by the consolidation of the granitic magmas that intruded into their respective areas, and when "N" of the biotite in the granites which crystallized out at that time is relatively large, they contain generally plenty of allanite as accessory in all other regions except Gyoja-Yama.
(2) Between Gyoja-Yama granite (bearing little allanite) and Hiéi granite (bearing plenty of allanite as accessory), there is a difference in the population mean of Fe content in biotite, though it is difficult to assert that any difference exists in that of Mg content: And "F" of the biotite of Hiéi granite takes a higher value than that of Gyojo-Yama granite.
(3) The pegmatites of Tanakami-Mikumo grew out of the pegmatitic fluids derived from the granitic magmas which participated in the genesis of the nearby granites. When "N" of the biotite in the pegmatites of the above fluids is relatively large, the pegmatite has plenty of allanite which crystallized out as accessory.

Now, when we compare Table 1 with Table 5 B, it is quite obvious that biotite-content in the granite which contains biotite with a larger "N" is greater than that in the granite which contains biotite with a smaller "N". And from Table 2 it is also evident that the value of $Mg+Fe^{\cdot\cdot}+Fe^{\cdot\cdot\cdot}$ of granite containing biotite with a larger "N" is greater than that of granite containing biotite with a smaller "N".

From the above facts the following conjectures may be allowed: "N" of biotite depends upon the magnitude of "N" of magma at the stage when the biotite crystallized out, and probably the larger is "N" of the magma, the larger is "N" of the biotite.

Next, about the crystallization process of olivin, pyroxene and plagioclase out of the mother liquid, a great deal has been studied, as is genellary known by N.L. BOWEN and his co-workers; but as for biotite and hornblende, the case is quite different; no experiment* has been done for making their crystallization process clear. Consequently, there exist two extremely different views regarding the crystallization stage of these minerals as described in the paragraph (B) and we are at a loss which to take.

Should we be allowed, however, to analogize the crystallization process of biotite from that of olivin or pyroxene, the following may be assumed:
Comparing the two stages when biotite with larger "F" and biotite with smaller "F" respectively crystallized out, "F" of granitic magma at the former stage is bigger

* In all the synthetic biotite investigations, D. D. GRIPORIEV[42] adopted composition of starting melt corresponding to the ratio of oxides in the formula of the biotite synthesized by him, while T. A. KOHN & R. A. HATCH[43] used composition of starting melt by adding 50 mol. per cent of fluor to the ratio of the oxides in the formula of the biotite synthesized by them.

What these experiments suggest about the relation between components of biotite in granite and those of the magma which crystallized out the mineral is of little import as compared with the suggestions that Bowen and his co-workers' synthetic experiment of plagioclase, alkali-feldspar, olivin, etc. give.

than that at the latter stage. And as for the two granitic magmas, in the time when one crystallized out biotite with larger "F" and the other with smaller "F", "F" of the former is bigger than "F" of the latter.

Thirdly, as described in (B), both allanite and biotite might be contemporaneously crystallized out of granitic magma; therefore it may be possible to compare "N" and "F" of one granitic magma with those of the other at the stage when allanite crystallized out of those magmas, according to the comparison between the corresponding cases of two biotites.

When the three facts abstracted at the head of this paragraph are reasoned out from the above three consequences, the following may possibly be true:

As regards the regions treated in this paper, when "N" of granitic magma or of pegmatitic fluid intruding into its respective regions was relatively large at the crystallization stage of biotite, plenty of allanite as accessory was generally crystallized out at the approximately same time as biotite*. But in only one case of the granitic magma which intruded into the Gyoja-Yama region, the above-mentioned is not true: that is to say, it seems that "N" of the granitic magma was relatively large at the above-mentioned stage, though little allanite was crystallized out. That exception seems to be closely related to the 2nd in the abstract at the head of this paragraph; in other words, closely related to the fact that, at the crystillization stage of biotite, "F" of the granitic magma of Gyoja-Yama might be lower than that of Hiéi which might be inseparably bound up with Gyoja-Yama magma from the geological point of view. Namely, it seems that the magnitudes of both "N" and "F" of granitic magma or pegmatitic fluid (at the crystallization stage of biotites) were not a little related to the fact whether plenty of allanite was crystallized out or not.

In truth, so far as the regions treated here are concerned, when both "N" and "F" of biotite contained either in granite or in pegmatite are relatively large; plenty of allanite as an accessory ingredient is certainly found in that rock. Therefore we may safely assume that when both "N" and "F" of either granitic magma or pegmatitic fluid were relatively large at the crystallization stage of biotite, plenty of allanite as accessory was crystallized out at the approximately same time as biotite.

Of course even if we consider merely of the fact that allanite is composed of such principal components not only as Fe, but as Ce, Ce-group rare earth elements, Ca, Al and Si as shown in Table 8[28)41)], it may be impossible to assume that the condition** on which plenty of allanite crystallizes out depends solely upon the

* Concerning the granite of all other regions except Gyoja-Yama, plenty of allanite is witnessed to come out of the melanocratic, schlieren-like parts. That fact is the good evidence which points out the following:
At the stage biotite crystallizing out of the magma which produced the above schlieren-like parts, "N" of the magma may have been relatively large.

** Concentration of Ce, Ce-group rare earth elements and Ca in magma is a sine qua non for allanite to crystallize out. That is to say. even if granitic magma had large "N" and "F", it might not happen that plenty of allanite should crystallize out without sufficient concentration of Ce-group rare earth elements and Ca. The fact that granite bearing plenty of allanite as accessory has often more or less paragenetic sphene and hornblende, may be an evidence for the above.

Table 8. Chemical compositions of allanites.

loc.	SiO_2	Al_2O_3	Fe_2O_3	FeO	CaO	MgO	MnO	ThO_2		Ce_2O_3
Mié	31.33	16.36	8.41	10.10	9.70	0.03	1.11	1.39		9.41
Hiéi	31.86	17.47	2.55	10.14	10.89	0.80	1.18	1.83		10.30
loc.	$(Ce)_2O_3$	$(Y)_2O_3$	TiO_2	SnO_2	K_2O	Na_2O	CO_2	H_2O+	H_2O-	total
Mié	9.88	0.10	—	—	—	—	—	1.56	0.76	100.14
Hiéi	9.96	0.64	0.88	0.47	0.08	0.06	0.28	1.47		100.86

quantity of "N" and "F" of granitic magma at the above-mentioned stage.

As for the regions, however, which the writer has treated of, there seems to be no denying that the above is one of the conditions*.

Conclusion

The follwing are the summarized conclusions of this study:

(1) The pegmatites embedded in the Tanakami-Mikumo granite-stock grew out of the pegmatitic fluids produced by the granitic magma which participated in the genesis of its nearby granite, and the early crystallized biotite (the biotite of the outer zone) contains more Mg than the late-crystallized biotite (the biotite of the inner zone), but the reverse with Fe. This fact means that Fe/Mg increased as pegmatitic fluids of the region got into later stages.

(2) As regards the biotites of the Hiéi and Gyoja-Yama granites which are closely related with each other from the geological point of view, it has been found that the statistical comparison is possible regarding the mafic contents of those: and the population mean of Fe contents in the biotites of Hiéi granite-stock is not equal to that of the Gyoja-Yama one, whereas it is difficult to assert that the population mean of Mg content in the former is not equal to that of the latter.

(3) As regards the regions treated here, when both "N" and "F" of the biotite contained in a granite or a pegmatite are relatively large, plenty of allanite as accessory is certainly found in that rock. Then, it seems that the allanite of that rock was crystallized out at the approximately same stage as biotite, and so by the magnitudes of "N" and "F" of the biotite may be interpreted those of "N" and "F" of the granitic magma or pegmatitic fluids at that stage. Therefore it may be possible to assume that when both "N" and "F" of granitic magma or pegmatitic fluid were relatively large at the stage when biotite was crystallized out of that magma or fluid, plenty of allanite as accessory was certainly crystallized out of that at the approximately same time as biotite.

* The magnitude of "N" or "F" may denote a stage of magmatic differentiation, but this problem has no direct connection with this study, so we leave it untouched.

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