MEMOIRS OF THE COLLEGE OF SCIENCE, UNIVERSITY OF KYOTO, SERIES B,
Vol. XXIV, No. 4 Geology and Mineralogy, Article 7, 1958

Studies on Granitic Pegmatites

Magnesium and Iron Contents of Biotites of Small Size in Granites and Pegmatites* Part 1

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(Received Sept. 30, 1957)

Abstract

For the study on magnesium and iron contents of biotites of small size in granites, no suitable method has yet been found. In this paper it is reported that, using the spectrochemical method the present writer previously reported, he has made a systematic study of magnesium and iron contents of biotites of small size in the granites covering nearly the whole area of Tango, Oku-Tango and Gyoja-Yama districts, the study of Fe and Mg contents of biotites in those of other regions being included.

Introduction

Biotites are the most predominant of all mafic minerals in granites and granitic pegmatites, and the study of the characteristics of Mg and Fe contents in biotites of those rocks is, therefore, requisite to the study on granitic pegmatites and granites. Relations between chemical composition and optical character of biotites, however, are very complex, and hence no suitable optical methods like what are used on the study of plagioclase has yet been found for the study on the chemical characteristics of biotites in granites. In spite of the endeavors paid by researchers,[1] progress of the study has been made very slowly up to the present as compared with the study on plagioclase.

From this point of view, the present writer has made a study of the granite-stock covering Gyôja-Yama district and the granite-batholith covering Tango and Oku-Tango district. For the quantitative determination of Mg and Fe contents in biotites[2] of small size he has devised a new method. The results obtained disclose noticeable facts on the contents of Mg and Fe in biotites. Comparisons are made with the study of biotites in granites covering Hiéi, Tachiki-Kwannon, Narukawa, Shigaraki and Mikata districts.

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* A part of the present paper has been published in Jour. Geol. Soci. Jap., 63, 422, (1957), with the title "Trace elements in biotites (part II)."

Sampling and Analytical method

Granite samples were collected at the spots marked with solid circles in Fig. 1, from A to D. Biotites in them were picked out, torn off along their cleavage planes so thin as to be transparent, purified under the microscope and powdered in an agate mortor, and then their magnetic impurities were removed by a strong

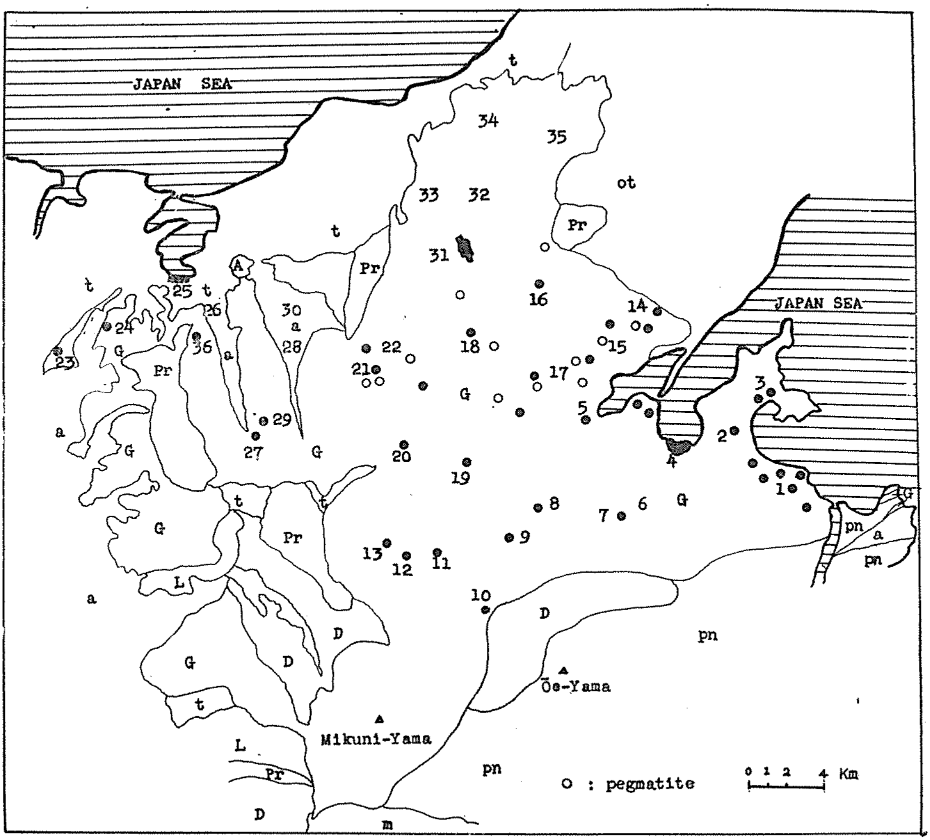

Fig. 1, A. Map of the Tango and Okutango district.

1 Yura	10 Yamakou	19 Yuwaya	28 Sano
2 Kunda	11 Taki	20 Nakafujigamori	29 Ichinono
3 Odazyukuno	12 Oku-Taki	21 Ôro	30 Shimosano
4 Miyazu	13 Shibo	22 Masudome	31 Mineyama
5 Yuwataki	14 Nariai	23 Tazuruno	32 Tanba
6 Yuwado	15 Otokoyama	24 Mié	33 Amino
7 Sekigafuchi	16 Kôbe	25 Kumihama	34 Yasaka
8 Atsue	17 Mié	26 Ama	35 Mizotani
9 Sakuranouchi	18 Chôzen	27 Kawakami	36 Yuwatetôge

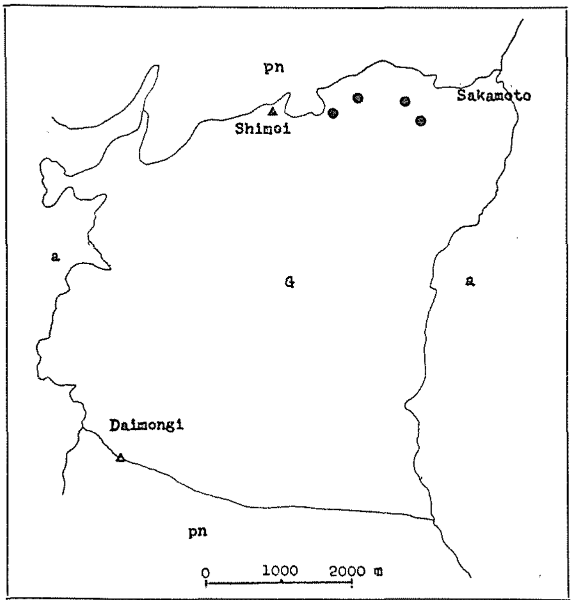

Fig. 1, B. Map of the Hiéizan district.

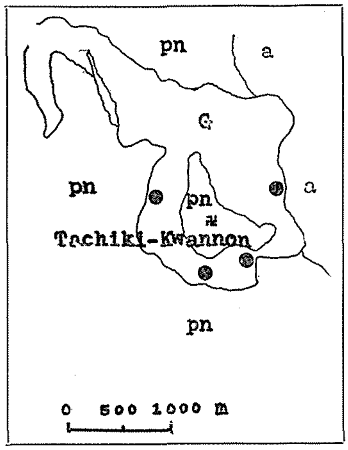

Fig. 1, D. Map of the Tachiki-Kwannon district.
G: granite D: diorite and serpentine Pr: propylite L: liparite t: tertiary ot: older tertiary pn: palaeozoic a: alluvium

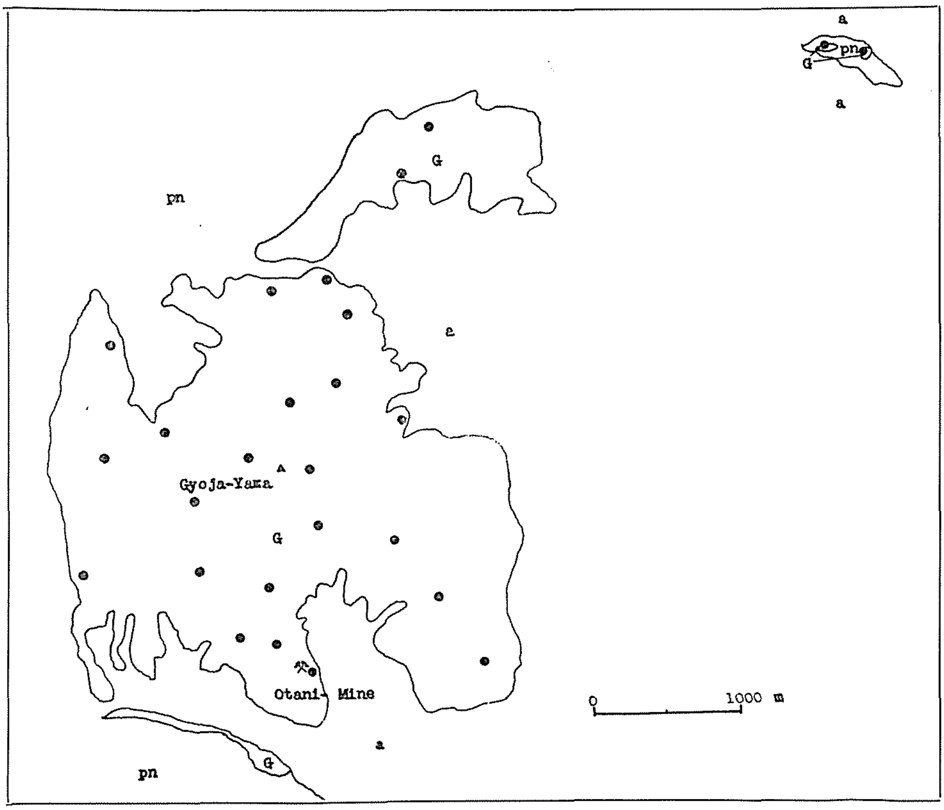

Fig. 1, C. Map of the Gyoja-Yama, Kameoka City.

magnet and a sensitive test* was attempted to see whether magnetic impurities still remained or not.

Analytical methods were already announced in the Memoirs of the College of Science, University of Kyoto, Series B, Vol. 23, No. 2[2] and in the Journal of the Spectroscopical Society of Japan Vol. 6, No. 1.[2]

Analytical results of iron and magnesium contents in biotites

In Tables from 1 to 6 there are shown the analytical results of iron and magnesium contents in biotites in granites of Tango and Oku-Tango, Gyoja-Yama, Hiéizan, Hira, Tachiki-Kwannon, Shigaraki, Narukawa and Mikata districts.

Consideration in detail

A. Biotites in pegmatite[3], wall granite[3] and nearby granite[3] of Ôro, Mineyama Town, Naka district, Kyoto Prefecture

This pegmatite is of an irregularly lenticular or cucumber-shaped body which can be divided into the following four zones: 1) graphic granite zone rich in biotites of bamboo leaf shape, 2) graphic granite zone poor in biotites, 3) perthite zone, and 4) quartz zone (the most inner zone).

Biotite samples Nos. 01, 02 and 03 were collected at random from the zone No. 1 and a large crystal of the biotite about 5 cm (on 001), from the perthite zone. Sample Nos. G1 and H1 were each collected from wall granite (G1) and nearby granite (H1).

The host rocks are as follows:

Granite sample No. G1: This rock belongs to a leucocratic medium-grained biotite granite, occupying the wall of the pegmatite and its neighbourhood. It consists essentially of quartz, plagioclase (mostly oligoclase), perthite, and a few biotites, and accessorily of apatite, hematite and magnetite. Pleochroism of biotite is: X...pale yellow, Y...brown, Z...dark brown.

Granite sample No. H1: This rock belongs to a leucocratic medium-grained biotite granite, lying in Ôro district. It is composed principally of quartz, plagioclase (mostly oligoclase), perthite and a few biotites, with apatite and magnetite as accessory ingredients. Pleochroism of biotite is: X...pale yellow, Y...borwn, Z...dark brown.

Host rocks of biotite sample Nos. 01, 03 and 04: These rocks are the graphic granites, which are composed principally of quartz, perthite and a few biotites of bamboo-leaf shape, with muscovite, as accessory ingredients. Pleochroism of biotite is: X...pale Yellow, Y...greenish brown, Z...brown.

* Their sizes (on 001) are commonly ca. 3–4 mm, but rarely come up to ca. 2 cm, Colours of biotites are generally brown, but occasionally green or some other colour. Biotites rarely have zonal structures concerning colours. In this paper the relations among iron and magnesium contents in them, their colours, sizes and zonal structures are discussed.

Table 1. Mg and Fe contents contained in biotites of granite specimens from the Tango and Oku-Tango district.

sample No.	Mg %	Fe %	atomic ratio Mg/Fe+Mg	Locality and Note
B. 8	6.0	17.85	0.392	Nariai
B. 5	4.2	18.9	0.338	Nishitani
B. 12	5.16	17.92	0.397	Ikaga
B. 11	8.28	18.06	0.512	Kôbe
B. 14	7.32	19.04	0.468	Mié
B. M2	6.96	22.12	0.418	Mié
B. 92a	6.48	16.17	0.474	Chozen (Nagaoka)
B. 30b	4.92	20.95	0.349	Chozen (Kami-yamada)
BHl	7.08	12.88	0.557	Masudome
BGl	6.72	11.83	0.558	Ôro
BTK.	5.76	14.70	0.473	Takidani
B. B4	8.40	17.78	0.521	Nakafujigamori
B. 10	5.88	18.34	0.411	Yuwaya
BKA	7.32	13.65	0.551	Yuwate-Toge
55	2.58	23.00	0.205	Ichinono. color: greenish brown
56	2.70	23.54	0.208	do.
B. 6	5.10	15.75	0.427	Mié (Miyanosita)
B. 7	4.02	20.65	0.309	Tazuruno
0.3	5.88	14.77	0.478	the pegmatite of Ôro
0.1	5.58	14.00	0.478	do.
0.4	5.88	15.05	0.473	do.
Bôro L.c.	5.10	16.31	0.418	do.
Tan. 1	4.8	19.81	0.357	Yuwataki
Tan. 2	4.62	19.18	0.356	Miyazu
Tan. 4	5.04	17.57	0.398	do.
Sak.	6.60	19.74	0.434	Sakuranouchi
Sek.	7.20	18.55	0.470	Sekigafuchi
Tan. 7	3.84	22.05	0.285	Kunda
Tan. 11	5.04	18.55	0.383	do.
Tan. 12	5.10	23.45	0.333	Yura
Tan. 15	3.96	21.00	0.302	do.
Tan. 16	3.30	18.27	0.293	do.
Tan. 17	3.78	21.00	0.294	do.
BYS	4.86	21.70	0.341	do.

Table 2. Mg and Fe contents in biotites of granite specimens from Gyoja-Yama district.

sample No.	Mg %	Fe %	atomic ratio Mg/Fe+Mg
Ts. 43, 1	6.12	16.10	0.465
Ts. 46	5.22	16.80	0.410
BKa 2	6.30	13.02	0.526
BKa 3	6.18	16.45	0.463
BKa 3L	6.90	17.15	0.480
8	6.42	19.60	0.430
13	7.14	16.59	0.498
Yun.	6.12	14.70	0.489
97	7.62	16.80	0.510
38	7.08	15.96	0.505
57	5.58	15.61	0.451
88	4.14	19.25	0.330
6	6.12	16.17	0.465
6bn	6.36	16.45	0.465
6L	5.88	17.50	0.431
33	7.08	19.81	0.450
76	4.44	14.35	0.416
71	5.04	18.27	0.387
4	6.54	15.47	0.492
9	6.66	13.93	0.523
17	5.28	16.1	0.430
27	4.92	15.82	0.417
52	5.16	16.66	0.415
69	6.12	16.87	0.452
75	6.78	18.27	0.460
35	5.16	20.30	0.368
65	5.16	17.50	0.406
65	4.38	16.66	0.377
68	6.18	15.96	0.470
70	5.34	15.47	0.431

Table 3. Mg and Fe contents in biotites of granite specimens from Hiéi and Hira districts.

sample No.	Mg %	Fe %	atomic ratio Mg/(Fe+Mg)	Locality and note
Hiéi. 1	4.32	21.14	0.320	Hiéi
Hiéi. 3	4.32	23.45	0.298	do.
Hiéi. 6	5.58	22.05	0.368	do.
Hiéi. 8	6.18	19.25	0.424	do.
Hiéi. 8	6.06	19.46	0.417	do.
Hira. 1	6.00	17.15	0.446	Hira

Table 4. Mg and Fe contents in biotites of granite specimens from Tachiki-Kwannon district.

sample No.	Mg %	Fe %	atomic ratio Mg/(Fe+Mg)	Locality and note
Tachi. 70	0.858	19.60	0.094	brown
Tachi. 6	0.132	16.31	0.018	
Tachi. 65	0.156	16.45	0.021	brown
Tachi. 65	0.150	13.09	0.026	pale brown
Tachi. 11	0.090	18.55	0.011	brown
Tachi. 11	0.228	20.16	0.025	greenish brown
Tachi. 11	0.138	21.35	0.015	green

Table 5. Mg and Fe contents in bioties of granite specimens from the other regions.

sample No.	Mg %	Fe %	atomic ratio Mg/(Fe+Mg)	Locality and note
Kas. 16	2.04	21.70	0.178	Narukawa, Nara Prefecture.
Kas. 16	2.04	21.84	0.177	do.
R. 10	3.36	19.74	0.281	the southern area of Shigaraki
Mk. 178	2.16	17.92	0.216	Mikata District, Fukui Prefecture.

Table 6. Mg and Fe contents in biotite specimens from the Ôro pegmatite, wall granite and nearby granite.

occurrence	color	Mg %	Fe %	atomic ratio Mg/Fe+Mg	sample No.
in nearby granite	X : pale yellowish brown	7.08	12.88	0.557	BHl
in wall granite	Y : brown Z : blackish brown	6.72	11.83	0.558	Gl
in the graphic granite zone of pegmatite	X : pale brown	5.88	14.77	0.478	0.3
	Y : brown	5.58	14.00	0.478	0.1
	Z : dark brown	5.58	15.05	0.473	0.4
in the perthite zone of pegmatite	Y : brownish green	5.10	16.31	0.418	BôroLc

The analytical results of Fe and Mg contents in them appear in Tables 1 and 6.

Now, considering from the shape of the pegmatite, its structure, spatial relationship and similarities in composition between the pegmatite and the nearby granite, it seems that this pegmatite must have been formed out of residual fluid from granite in a system closed, but not so tightly that such materials as volatile substances might not escape into the wall rock during crystallization.

Judging from the paragenetic sequence of minerals, the sequence of development contrasting lithologic units and the growth directions of individual crystals[4], it also seems that primary crystallization within pegmatite must have been produced inward from its wall.

As pointed out by FRONDEL[5], CAMPBELL and SCHENK[6] etc., a large crystal in a pegmatite was crystallized out in a short time, on account of high rates of growth of crystals during the period of crystallization of pegmatite fluid.

For the reasons mentioned above, each group of biotites—(BH1, BG1), (01, 03, 04), and Bôro L,—was crystallized out from the granitic magma and pegmatitic fluid respectively, in the order from biotites BH1 and BG1 to the biotite Bôro L.

Through the above-mentioned and Table 6, the following relationships may be summarized:

(1) Mg content in biotites in granites is higher than that of the pegmatite, but as to Fe content this relation is entirely reverse.

(2) In the pegmatite, the early crystallized biotites are slightly richer in the content of Mg than the later crystallized ones, but as to Fe content this relation is reverse.

B. Biotites in the granite of Tachiki-Kwannon district, Shiga Prefecture

As shown in Fig. 1, b, the granite of this district forms a stock with an area of about 3 square kilometers, which is a branch of the batholith of Tanakami and Mikumo districts, and a roof-pendant of the Palaeozoic remains in that stock. The rock belongs to coase-grained muscovite biotite granite. It consists essentially of quartz, plagioclase (mostly oligoclase, the inner part of which is often sericitized), small microcline, perthite (in which corroded quartzs are closed), biotite and muscovite, with apatite and zircon, as accessory ingredients. The pleochroism of sample No. Tachi. 70 is: X...light pale yellow, Y...pale brown, Z...brown. Sample Nos. Tachi. 65 and Tachi. 11* is zonally changed concerning colors, as shown in Fig. 2, A and B.

In Table 7 are shown the analytical results of those biotites. Mg content in mica sample No. Tachi. 70 is extremely lower than that in common biotites and this mica is a representative brown one in the granite of Tachiki. Fe content in biotite sample No. Tachi. 11 becomes gradually richer in the order from the brown part of it to the green, but Mg content is nearly constant. The mode of zoning about the color of biotite sample No. Tachi. 65 is entirely reverse to the case in

* They were separated into zones corresponding to the variation of color for analytical samples.

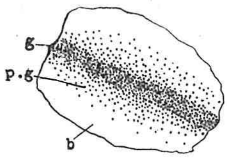

Fig. 2, A. Sketch of mica sample No. Tachi. 11
g : green
p·g : pale green
b : brown

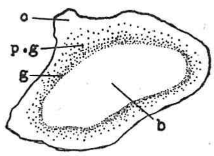

Fig. 2, B. Sketch of mica sample No. Tachi. 65
g : green
p·g : pale green
b : brown
c : colorless

biotite sample No. Tachi. 11 and the outermost part of the former is colorless. Fe content in sample No. Tachi. 65 becomes gradually poorer outward, but Mg content is nearly constant.

T. OGAWA discussed the transformation from a brown mica in the pegmatite of Tanakami district into a muscovite. And in his study, he analyzed three mica samples giving the results shown in Table 8. Mg content in these biotites is nearly constant but Fe content gets poorer in the order from sample No. 1 to No. 3.

The present writer found a similar tendency among zones of one and the same biotite in granite (sample No. 65).

These results may denote that affinity in composition between the pegmatitic fluid producing the pegmatite of Tanakami and the granitic magma producing the granite of Tachiki may have been strong.

Mg content in biotite sample No. Bôro L of the Ôro pegmatite is greatly higher than that in brown mica of the Tanakami pegmatite, and the same tendency appears in Mg content of biotites in granites of Tachiki-Kwannon and Ôro.

This may be one of the evidences which indicate that features on Mg and Fe contents in granitic magmas reflect themselves not only on Mg and Fe contents in the biotites of the granites produced from those magmas, but also on those in biotites of pegmatites formed out of residual fluids from those granites.

Table 7. Mg and Fe content in biotites of granites specimens from Tachiki-Kwannon district.

sample No.	color	Mg %	Fe %
Tachi. 70	Y : brown	0.858	19.60
	Y : brown	0.090	18.55
Tachi. 11	Y : pale brownish green	0.228	20.16
	Y : green	0.138	21.35
Tachi. 65	Y : brown	0.156	16.45
	Y : almost colorless partially pale green	0.150	13.09

Table 8. Mg and Fe contents in mica specimens from the Tanakami pegmatite[8].

note	Mg %	Fe %
1. dark brownish green (similar to biotite)	0.195	14.6
2. gray (the color of its inner parts is brownish)	0.774	8.9
3. do.	0.259	2.7

C. a few biotites in the granites of Hiéi and Hira districts, Shiga and Kyoto Prefectures

As shown Fig. 1, B, the granite of Hiéi district forms a stock with an area of about 25 square kilometers surrounded by the Palaeozoic stratum. The granite of Hira also forms an elongated stock surrounded by the palaeozoic, which lies about 10 kilometers north of Mt. Hiéi. As regards these districts, only a few biotite samples have been analyzed, so it is impossible to discuss about all these districts. The relation between the colours of biotites of these granites and the Mg and Fe contents is chiefly discussed in this paragraph.

Host rocks of biotite samples used for the analysis are located along the neighbourhood of the zone in contact with the Palaeozoic Stratum as shown in Fig. 1, B. These rocks belong to medium-grained biotite granites. They consist essentially of quartz, plagioclase (mostly zoned crystal of oligoclase), perthite (mostly anhedral), microcline (rare) and biotite, and accessorily of apatite, allanite (crystals of about 0.5 cm length are aften found), chlorite and a few magnetites.

Pleochroism of most biotites in granite samples Hiéi 1 and Hiéi 3 is: X...pale yellow, Y and Z...grass green. Pleochroism of their few biotites: X...pale brownish yellow, Y...brown, Z...dark brown. The biotites analyzed belong to the former pleochroism. In granite sample No. Hiéi 6, the colour of biotite is mostly brown, but it rarely is brown in part and green in part, as shown in Fig. 3. The biotite analyzed belongs to the latter. Biotites of granite sample Hiéi 8 belong to the brown only. Analytical results of these biotites appear in Table 9. When the brown is compared with the green, Mg percentage in the former is higher than in the latter, but as to Fe percentage the relation is reverse.

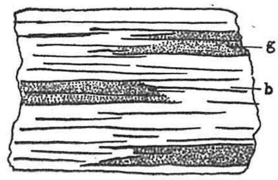

Fig. 3. Sketch of mica sample No. Hiéi 6
g: green
b: brown

Each of Fe and Mg percentages in biotite sample No. Hiéi 6 lies respectively between Fe percentage in the brown and that in the green, and also between Mg percentage in the brown and that in the green. The result is quite natural, for this biotite sample is regarded as a mixture of brown and green. From the foregoing examples, it is ascertained that Mg and Fe percentages in biotites of the granite change according to differences in their colours.

The granite sample No. Hira 1 belongs to a medium-grained biotite granite and consists of the component minerals similar to those of Hiéi granite, but allanites are not found in it.

It may be noticeable that Mg and Fe percentages in the biotite of granite No. Hira 1 (Table 3) belong to the field of the principal series* in the correlation diagram of Mg and Fe in the biotite of Oku-Tango and Tango districts shown in Fig. 6, but those in the biotite of granite sample No. Hiéi 8 belong to the special field I.**

D. Biotite of the granite of Gyoja-Yama[9] district, Kameoka city, Kyoto Prefecture.

As shown in Fig. 1, C, the granite of Gyoja-Yama district forms a stock with

*, **: They are described fully in the paragraph E.

an area of about 25 square kilometers surrounded by the palaeozoic stratum, and scheelite-pegmatite veins of the Ôtani mine are embedded in it. The granite of this district belongs to medium-grained biotite granite consisting essentially of quartz, normally-zoned or oscillatory-zoned plagioclase (mostly oligoclase), orthoclase, microcline (rare), anhedral perthite and biotite (its pleochroism: X...pale brown, Y...reddish brown and Z...dark reddish brown) and accessorily of apatite, zircon, monazite, muscovite, magnetite and sphene (rare), no allanite. Where the granite is in contact with the Palaeozoic, the inner part of plagioclase often sericitized, and myrmekite often surrounds the margin of the plagioclase, and micrographic textures of quartz and orthoclase are found.

Generally speaking, however, granites of this stock are poor in the variation of the rock facies and homogeneous (in Table 10[8]) is shown the chemical composition of a granite of this district).

As shown in Fig. 1, C. biotite samples are located at random all over the outcrop of the stock, and accordingly it is possible to regard that the analytical results of those biotites show features on Mg and Fe contents in biotites in the granite-stock.

Biotite sample Nos. 6, 6 L and 6bn shown in Table 11 were picked out from one and the same granite specimen, and the size of the crystal of the first is about 0.4 cm (on 001), that of the second about 1.5 cm and that of the third (picked out from a nest of biotites) about 0.3 cm respectively. Biotite samples Nos. BKa 3 and

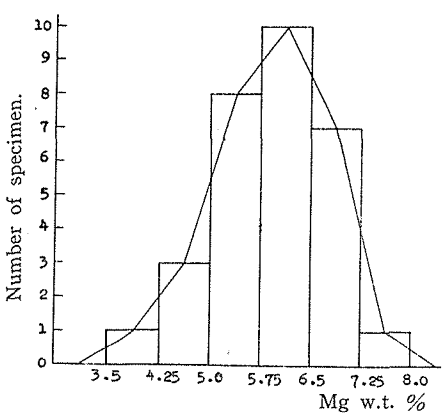

Fig. 4, A. Frequency distribution diagram of Mg in 30 specimens of biotites

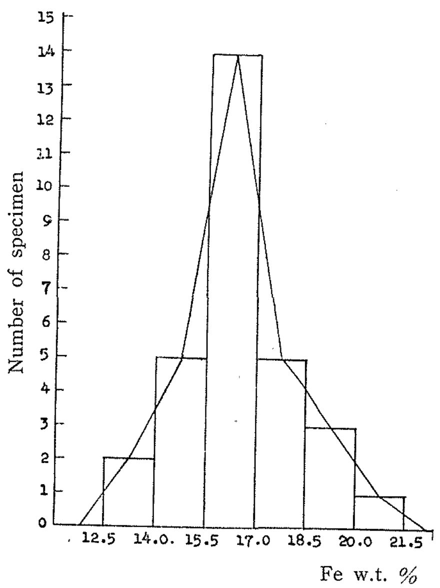

Fig. 4, B. Frequency distribution diagram of Fe in 30 specimens of biotites

Table 9. Mg and Fe contents in biotites of granite specimens from Hiéi-Zan.

sample No.	note	Mg %	Fe %	atomic ratio Mg/Fe+Mg
Hiéi. 8	X : pale brownish green	6.08	19.25	0.424
	Y : brown			
Hiéi. 8	Z : dark brown	6.18	19.46	0.417
Hiéi. 6	brown mica (partially green)	5.58	22.05	0.368
Hiéi. 3	X : pale yellow	4.32	22.14	0.298
	Y : pale green			
Hiéi. 1	Z : grass green	4.32	23.45	0.320

Table 10. Chemical compositions of the granite of the Gyoja-Yama district.[8]

SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	H_2O (+)	total
72.16	0.35	13.93	0.49	2.23	0.26	0.63	2.02	3.61	3.23	0.28	0.81	100.00

Table 11. Mg and Fe contents in biotites of granite specimens from the Gyoja-Yama district.

sample No.	size	Mg %	Fe %	atomic ratio Mg/Fe+Mg
6	about 0.4 cm	6.12	16.17	0.465
6bn	about 0.3 cm	6.36	16.45	0.465
6L	about 1.5 cm	5.88	17.5	0.431
BKa3	about 0.4 cm	6.18	16.45	0.463
BKa3L	about 1.8 cm	6.90	17.15	0.480

Table 12. A Frequency distribution table of Fe in biotites of granite specimens from the Gyoja-Yama.

class	class value	frequency
12.5-14.0	13.25	2
14.0-15.5	14.75	5
15.5-17.0	16.25	14
17.0-18.5	17.75	5
18.5-20.0	19.25	3
20.0-21.5	20.75	1

Table 12. B. Frequency distribution table of Mg in biotites of granite specimens from the Gyoja-Yama.

class	class value	frequency
3.50-4.25	3.875	1
4.25-5.00	4.625	3
5.00-5.75	5.375	8
5.75-6.50	6.125	10
6.50-7.25	6.875	7
7.25-8.00	7.625	1

Table 13. Some statistical results.

	mean deviation	quartile deviation	standard deviation
Fe	1.24	1.05	1.66
Mg	0.69	0.61	0.84

BKa 3L were also picked out from one and the same granite specimen, and the former is about 0.4 cm and the latter about 1.5 cm in size. Any of those biotites is of the same colour and their pleochroism is: X...pale brown, Y...reddish brown, Z...dark reddish brown. The analytical results of those biotites are shown in Table 11.

Next, by examining the analytical results of biotites given in Table 2, the following are found: mean values of Mg and Fe percentages in all biotite samples analyzed are each 5.91 and 16.66 percent. Regarding Mg and Fe percentages divided into six ranges as variables, the frequency distribution diagrams have been drawn, giving the results shown in Fig. 5, A and B. From their shapes, it is recognized that these distributions seem nearly normal. The standard, mean and quartile deviations of Mg and Fe percentages have been calculated from the data shown in Table 12, and the results are given in Table 13. The mean deviation of each of Mg and Fe percentages is about 0.8 times as much as the corresponding standard deviation, and quartile deviation is also about two-thirds of the corresponding standard deviation. These results show that the frequency distributions of Mg and Fe percentages are normal

Summarizing the above, it is the following,* which may be one of evidences denoting that the granite of this district was crystallized from one homogeneous granitic magma:

(1) Any of the frequency distributions of Mg and Fe percentages is normal.

(2) Any of their standard deviations is extremely little.

E. Biotites of the granite of Tango and Oku-Tango districts, Kyoto Prefecture

As shown in Fig. 1, A, the granite[3] of this region forms a batholith, and shows various rock facies. That is to say, the granite covering the easten part of this batholith—from Yura to Kunda district—belongs to coarse-grained hornblende-bearing biotite granite, which consists essentially of quartz, plagioclase (mostly normally-zoned oligoclase, the margin of which is often surrounded by myrmekite), anhedral large perthite,** orthoclase (rare), biotite (its pleochroism is: X...pale yellow, Y...brown, Z...dark brown) and common hornblende (green), and accessorily of allanite (which is occasionally about 0.7 cm in size), sphene, epidote, apatite, magnetite and zircon.

In the western side of the above districts—from Miyazu to Yuwataki—the granite belongs to medium-grained biotite granite composed principally of quartz,

* It may be said that the variation of An percentages of plagioclases in a granite body of a district is fairly large, even in one granite specimen, but that of each of Mg and Fe percentages of biotites is very small, indicating that these percentages in biotities of one granite specimen nearly constant, in spite of differences in their occurrences and sizes. And the above may indicate that the range of the crystallization of the reddish brown crystallized primarily from granitic magma is extremely shorter than that of plagioclases.

** There are instances in which corroded plagioclase is often closed in perthite and perthite forms micrographic structure with quartz.

plagioclase (mostly normally zoned oligoclase, the margin or a part of which changes often into myrmekite), microcline (abundant), perthite, orthoclase, and biotite (its pleochroism is: X...pale yellow, Y...brown, Z...dark brown), with apatite, magnetite, zircon and hematite as accessory ingredients.

In the southern part of the above area—Yuwado, Sekigafuchi, Atsué, Sakurauchi and Yamakô districts, where there are diorite and serpentine adjoining to granite, the granite generally belongs to coarse- or medium-grained hornblende biotite granites which are composed principally of quartz, plagioclase (mostly oligoclase), perthite, orthoclase, common hornblende (green) and biotite (its pleochroism is: X...pale brownish yellow, Y...brown, Z...dark brown), with apatite, sphene and magnetite as accessory ingredients and the granite lying in Sakurauchi district contains abundant plagioclase (with notably zonal structure).

The granite covering the south-western part of the above region—Taki, Oku-Taki and Shibo districts also belongs to coarse-grained hornblende biotite granite.

In the north-western part of Yuwataki district (Yôrô, Nariai, Otokoyama, Kôbe, Mié, Chôzen, Takitani, Yuwaya, Nakafujigamori and Toyooka districts),—these districts are continuous to Ôro and Masutome districts on their southern, eastern and nouth-eastern sides. The granite belongs to medium- or coarse-grained biotite granite or hornblende-bearing biotite granite, which consists essentially of quartz, plagioclase (mostly normally zoned oligoclase: the margin or a great part of which changes often into myrmekite), perthite, orthoclase (there are instances in which orthoclase forms graphic granite structure with quartz), microcline (rare) and biotite (its pleochroism is: X...pale brown, Y...brown, Z...dark brown), and accessorily of common hornblende* (green), allanite, epidote, sphene, apatite, zircon, magnetite, hematite, chlorite and muscovite contained in nearby granites of pegmatites (granite sample Nos. P10, T1 and K1). Among accessory minerals, allanites are the most noticeable, because they are contained in granites of Yôrô, Ikaga, Mié, Kobe. Chozen and Yuwaya districts, and especially in nearby granites of allanite-pegmatites[3)] of Mié, Taniuchi, Kôbe and Otoko-Yama many allanites are contained and this may be one of the evidences denoting affinity in composition between those pegmatites and their nearby granites.

In the western side of Ôro and Masudome districts—Tazuruno, Mié, Kumihama, Ama, Kawakami and Sano districts—, the granite belongs to coarse- or medium-grained biotite granite. In the area along the Japan Sea—Kumihama, Shimo-Sano and Ama districts—and in the northern part of the area from Nagaoka to Kôbe (Mineyama, Tanba, Amino, Yasaka and Mizotani), the granite has been severely weathered, and accordingly it was impossible to obtain fresh samples of granites of these districts. Now, the granite covering those regions, in general, consists

* Common hornblende as an accessory ingredidnt is contained relatively abundantly in granites of Mié and Yuwaya and Nakafujigamori districts—as previously stated, in the south-eastern, the southern and the south-western parts of Yuwaya and Nakafujigamori districts the rock is hornblende biotite granite—. Sphene is found in all granites except wall granites of pegmatites of Taniuchi and Mié.

essentially of quartz, plagioclase (mostly normally-zoned oligoclase; the margin or the inner part of which often changes into myrmekite), perthite, orthoclase, microcline (rare), and biotite (its pleochroism is: X...pale yellow, Y...brown, Z...dark brown), and accessorily of apatite, magnetite, hematite and sphene. Facies of granites are slightly remarkable; in two or three small regions described below. The texture of the granite of Miyanoshita is partly mylonitic. In Yuwate-Toge there is the extrusive body of the andesite in the northern side of that area—the rock contains calcites and limonites filling up the interstitial space among primary minerals, and the inner part of the plagioclase is mostly sericitized and quartz is often impregnated with many black spots, and these indicate that the granite was metamorphosed secondarily. In the fine-grained biotite granite of Ichinono which lies in the small area of the neighbourhood of the quartz-rich-pegmatite, large anhedral perthite is conspicuous, and myrmekite fills up the interstitial space among perthites and the conspicuous accessory minerals are magnetite, the mode of whose occurrence appears in Fig. 5 and biotite shows pleochroism (X...pale greenish brown, Y...greenish brown, Z...dark greenish brown). In short, granite of the above area, except a few small local regions, is similar to that of Yuwataki and Miyazu districts.

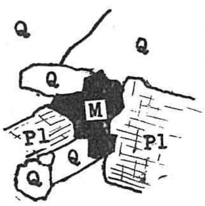

Fig. 5. Magnetite in granite sample No. 55.
M: magnetite
pl: plagioclase
Q: quartz

Granite, covering the area from Ôro to Masudome and embedding the fergusonite-pegmatite of Ôro,[3)] belongs to leucocratic medium-grained biotite granite, which consists essentially of quartz, plagioclase (mostly normally zoned oligoclase), perthite (abundant), orthoclase (poor), and biotite (its pleochroism is: X...pale yellow, Y...brown, Z...dark brown), and accessorily of apatite, hematite, and magnetite often occurring in the interstitial space among plagioclases, in the way similar to that in Fig. 5.

According to the above-mentioned, it seems that in this granite batholith the acidity of granite gradually decreases from the inner parts—Ôro, Masudome and etc.—, toward the outer parts—Yura, Sekigafuchi, Sakurauchi, Shibo, Okutaki and etc.—.

In Table 14[11)], the analytical results of a few granites of this region are shown.

The analytical results of Mg and Fe contents in biotites of the above granites are shown in Table 1.

In Fig. 6, Fe weight percentage of biotite has been plotted against Mg percentage of the same biotite* on the basis of the data given in Table 1, and through this figure it is noticed that excepting the biotites of the subordinate series I, there may be a high negative correlation between Mg and Fe percentages of biotites

* The ratio—atomic weight of Mg to that of Fe nearly equals 0.44/1, and hence for the purpose of studying relation in the number of atoms between Mg and Fe in biotites, it is more fitting to shorten the unit of the Fe axis into 0.45 times of that of the Mg axis. Fig. 6 has been drawn upon the above consideration.

Table 14. Chemical compositions of granite specimens of Tango and Oku-Tango district.

locality	Taniuchi	Ôro	Kunda	Yura	Odajukuno
rock	biotite[4] granite	biotite[4] granite	biotite[12] granite	hornblende[12] biotite granite	biotite[12] granite
anal.	M. TATEKAWA	M. TATEKAWA	not stated	not stated	not stated
SiO_2	75.38	75.52	74.05	73.20	72.41
TiO_2	tr.	0.13	—	—	—
Al_2O_3	13.74	13.73	14.26	14.23	14.82
Fe_2O_3	0.20	0.04	1.86	2.81	2.58
FeO	0.55	0.68	—	—	—
MnO	0.17	0.16	0.12	0.07	0.09
MgO	tr.	tr.	0.67	0.30	0.44
CaO	0.99	0.68	1.28	1.49	1.50
Na_2O	3.80	3.78	3.46	4.02	4.48
K_2O	5.00	5.48	3.80	3.22	3.39
H_2O (+)	0.23	0.45	—	—	—
H_2O (−)	0.20	0.15	—	—	—
Ign. loss	—	—	0.62	0.29	0.36
total	100.26	100.80	100.12	99.63	100.07

found in the granite-batholith. Calculating the correlation coefficient (γ) between Mg and Fe percentages in biotite and making the test;

$\gamma = -0.739 \qquad t = 4.94$

critical values for it, 20 D. F. are:

5 percent 2.086   1 percent 2.845

The value found for t is much larger than the critical 1 percent value for t. The conclusion is that there is a high negative correlation between Fe percentage and Mg percentage in biotites.*

From the above, it is recognized that the total number of Mg and Fe atoms in the biotites of the granite-batholith is roughly the same, in spite of the differences of rock facies, and Mg content in a biotite changes compensationally with the change of Fe content, according to the variation of rock facies; and generally Mg content in biotites gradually increases and Fe content in them gradually decreases with increase of the acidity of granite.

The above fact may be one of the momentous evidences which denote that by the differentiation of one granitic magma was produced each of the various rock facies containing the biotites of principal series found in the granite-batholith.

* The writer gives to the group of these biotites the name of the principal series.

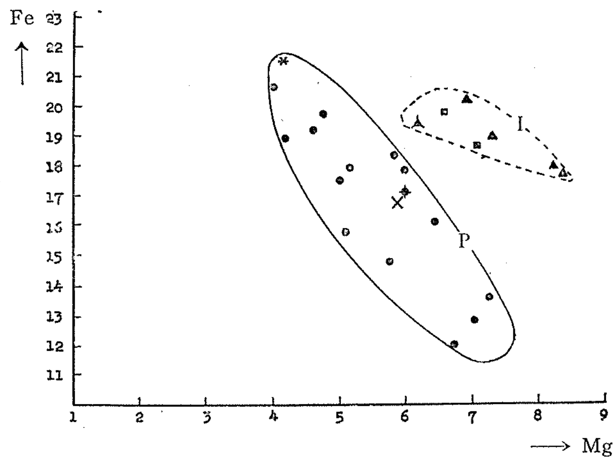

Fig. 6. Correlation diagram of Mg and Fe weight percentages in biotites.
● : A biotite of a granite specimen containing no allanite from Tango and Oku-Tango district.
▲ : A biotite of a granite containing allanite from Tango and Oku-Tango district.
■ : A dioritic granite from Tango and Oku-Taugo district.
× : The mean values of Mg and Fe percentages in biotites of granite specimens from Gyoja-Yama district.
⚲ : A biotite of a granite specimen from Hiéi.
✦ : A biotite of a granite specimen from Hira.
✻ : The mean values of Mg and Fe percentages in biotite of granite specimens from Yura and Kunda district.
P : Principal series.
I : Subordinate series I.

And also it seems that the granites containing the biotites of the subordinate series I were produced from the granitic magma differing in composition from that stated in the above or locally contaminated magma.

Then, considering the relation to pegmatites, it is clear that the biotites in the wall and nearby granites of the fergusonite-pegmatite[3)] (sample Nos. BG 1, BH 1) are situated in the part richest in Mg and poorest in Fe within the principal series shown in Fig. 6; the biotites in the nearby granite of the allanite-pegmatite belongs to the subordinate series I, and also, as already described in the paragraph A, it is fully considered that the pegmatites embedded in the granite of Naka district[3)] were formed out of residual fluid coming from the nearby granite of those pegmatites; therefore it may be concluded that fergusonite-pegmatite was formed out of the residual fluid coming from the granite which contains the biotite of the part richest in Mg but poorest in Fe within the principal series shown in Fig. 6, and that the allanite-pegmatite was formed out of residual fluid from granite containing the biotite of the subordinate series I.

Lastly, the mean values of Mg and Fe contents in the biotites of the granite of Gyoja-Yama district belong to the principal series in Fig. 6. This fact surely denotes that there is a strong affinity between the granitic magma producing the granite-batholith of Tango and Oku-Tango districts and that producing the granite-stock of Gyoja-Yama district.

F. Biotites of the granites lying in other few regions

According to Tables 1 and 5, in biotites of granites in Narukawa[10] and the south-western area of Shigaraki which belong to the Ryôke region each of Mg contents is much poorer than those in the granite of the corresponding facies in Tango and Oku-Tango region, but in Fe content, there is not much difference, and the scarcity in Mg is probably compensated by the abundance of Al, Mn and others. And when the spots representting Mg and Fe percentages in those biotites are plotted in Fig. 6, these are situated in the left and the lower part of the principal series. At all events, the above may be related to the difference in the origin of the granites in the above two regions.

Mg and Fe contents in the two mica granites of Mikata district, Fukui Prefecture are poorer than those of the granites of other regions except Tachiki-Kwannon region.

Host granites of those biotites are as follows: The granite of Narukawa: the granite belongs to coarse-grained hornblende-bearing biotite granite, which consists essentially of quartz, plagioclase (mostly oligoclase), perthite, orthoclase and biotite (its pleochroism is: X...pale brownish yellow, Y...reddish brown, Z...dark reddish brown), and accessorily of apatite, magnetite (rare). The granite of the south-western part of Shigaraki town: the granite belongs to coarse-grained biotite granite, which consists essentially of quartz, plagioclase (mostly oligoclase; its margin is often surrounded by myrmekite), perthite, microcline and biotite (its pleochroism is: X...pale yellowish brown, Y...brown, Z...dark brown), and accessorily of apatite and magnetite (rare). The granite of Mikata district: the granite belongs to medium-grained two-mica granite, which consists essentially of quartz, Plagioclase (mostly oligoclase), microcline (large size) and biotite (its pleochroism: X...pale yellowish brown, Y...brown, Z...dark brown), and accessorily of apatite and magnetite (rare).

Conclusions

In regard to Mg and Fe contents in biotites of granites, the main conclusions drawn from this investigation may be listed as follows:

(1) In the granite-stock of Gyoja-Yama district, frequency distributions of Mg and Fe percentages in biotites are each normal with very little standard deviations and it corresponds to the feature that the granite of this region is petrologically homogeneous.

(2) In the granite-batholith of Tango and Oku-Tango districts, there is generally a high correlation between Mg and Fe percentages in biotites as shown in Fig. 6 and these biotites form the principal series, except both the dioritic

granite and the granite containing a few allanites as accessory ingredients. The biotites of the above exceptional granites form the subordinate series I.

(3) In biotites of the granites both of Narukawa district and of the south-western area of Shigaraki town belonging to the Ryôke region Mg contents are poorer than those in biotites in the granite of Tango and Oku-Tango districts belonging to the inner zone of the south western Japan except the Ryôke region.

(4) In biotites of two-mica granites covering Tachiki-Kwannon and Mikata districts Mg and Fe contents are poorer than those in the biotites of the above districts.

(5) Mg and Fe contents in biotites of the granite have relation to their colours, but the former scarcely have any relation to either their sizes or their occurrences so far as the one granite specimen is concerned.

(6) Fe contents in biotites of the pegmatite of Ôro are richer than those in the biotites both of the nearby granite and of the wall granite, and that relation is reverse in the case of Mg contents. The same relation exists slightly also between the biotites of the pegmatite crystallizing out earlier and those later.

(7) Respecting each of Mg and Fe contents, there is a wide difference between the biotites in the nearby granite of allanite-pegmatite embedded in the granite of Oku-Tango district and those in the nearby granite of fergusonite-pegmatite.

The above may be one of the evidences which indicate that in chemical composition, there is a wide difference between the two pegmatite fluids which formed pegmatites of both types.

(8) As to each of Mg and Fe contents, there is a wide difference between the brown mica of large size of the Ôro pegmatite and that of the Tanakami pegmatite. And the same differences are also found between the two biotites in the nearby granites of both pegmatites.

The above may show that in chemical composition, there is a wide difference between the pegmatitic fluids which produced the pegmatites of both districts.

Acknowledgements

The writer offers his hearty thanks to Prof. A. HARUMOTO for many helpful guidances and advices and also is much indebted to Assist. Prof. H. YOSHIZAWA for plenty of helps, many instructions and guidances in the field of the Ryôke region. The writer expresses no less gratitude to Lecturer T. UEDA for many valuable advices and to Lecturer N. KAWAI for measuring magnetism of biotite samples.

He also wishes to thank Messrs. M. HIRATA, T. TSUTSUMI, T. ARAKI of the Geological and Mineralogical Institute of Kyoto University, Mr. Y. TSUKAWAKI of the Geological Survey of Japan and Mr. S. TANAKA for granite samples.

A part of this study was made by the Grant in Aids for Fundamental Scientific Research of the Ministry of Education and also the financial aid of the Hattorihokokai, to which is, lastly but not the less, due the present author's gratitude.

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