STRUCTURAL FORMULAS AND POLYMORPHS OF BIOTITES FROM THE SOUTHWESTERN OUTER ZONE-TYPE GRANITIC ROCKS, JAPAN

Rep. Fac. Sci., Kagoshima Univ. (Earth Sci., Biol.),
No. 15, p. 1–39, 1982.

STRUCTURAL FORMULAS AND POLYMORPHS OF BIOTITES FROM THE SOUTHWESTERN OUTER ZONE-TYPE GRANITIC ROCKS, JAPAN

By

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(Received July 1, 1982)

Abstract

Chemical analyses of fifty six biotites from granitic rocks of the Southwestern Outer Zone-type, those of which occur mainly within the Shimanto major belt in the outer zone of Southwest Japan, and X-ray diffraction powder data of twenty three biotites were examined to investigate the physicochemical natures such as structural formulas and polymorphs of the biotites. As a result, most of the analyzed biotites have the number of additional positive charge greater than 0.50 in the unit cell or 0.25 in the half-cell in the octahedral layers, and fall within the bivalent iron-dominant biotite area of the FOSTER's triangular diagram Mg, R^{3+} and Fe^{2+}. Meanwhile, 2M polymorph was identified by means of X-ray powder diffraction among polymorphs expected in the analyzed biotites. Chemical analyses of fifty six granitic rocks of the analyzed biotites were also summarized.

Introduction

This study is a part of a series of research, regarding physicochemical nature of mafic minerals of granitic rocks, that which has been carried on since 1963. To understand the physicochemical nature of biotites from granitic rocks of the Southwestern Outer Zone-type (SHIBATA, 1962), those of which have been reported by the present authors with respect to their petrochemical features, contamination-effects, geologic environments and emplacement mechanism (ŌBA, 1962a, c, d, e, 1966, 1967, 1974, 1977, ŌBA, and others, 1978), chemical analysis and X-ray powder diffraction were made of the biotites.

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Major attention will be given in this paper to summarize chemical analyses of the biotites from granitic rocks of the Southwestern Outer Zone-type and those of the granitic rocks of the analyzed biotites, and to review structural formulas and polymorphs estimated from X-ray diffraction powder data of the biotites. Most of these chemical and X-ray data are those which were used for writing tables and figures presented by the authors at the Annual Meeting of the Geological Society of Japan in 1964, and at the 1st, 7th and 9th Meetings of the IGCP Project No. 30, Circum-Pacific Plutonism held in California, U.S.A., in 1972, in Japan and Korea in 1977, and in Khabarovsk, U.S.S.R., in 1979, and at the 3rd Regional Conference on Geology and Mineral Resources of Southweast Asia held in Bangakok, Thailand, in 1978 (ŌBA, 1964, ŌBA and others, 1977, 1978, 1979). Chemical analyses of granitic rocks of the analyzed biotites and chemical analysis and X-ray diffraction powder datum of one hornblende coexisting with biotite were also given in this paper.

Chemical Analyses of Biotites from Granitic Rocks of the Southwestern Outer Sone-Type

Chemical analysis of mafic mineral such as biotite and hornblende from granitic rocks of the Southwestern Outer Zone-type has scarecely been reported till 1963. In 1964, chemical analyses of mafic minerals and a relation in chemical composition between mafic minerals and granitic rocks of the Southwestern Outer Zone-type of the analyzed mafic minerals were reported by ŌBA (1964) at first at the Annual Meeting of the Geological Society of Japan. Some of these chemical data were published out in 1966 as a product of a collaborative research (SHIBATA and others, 1966). However, the whole of chemical data have not been published out. Since 1977, chemical analyses of mafic minerals from granitic rocks of the outer zone of Southwest Japan have become to be reported by ŌBA and other (1977), YAMAMOTO (1978) and others.

Fifty six chemical analyses of biotites from granitic rocks of the Southwestern Outer Zone-type are tabulated in talbe 1. Analysis was made by a combined method of "standard" and either of "ion exchange resin and chelate titration (ŌKI and others, 1962)" or atomic absorption. Besides, electron microprobe analyses of eighteen biotites and seven hornblendes from Omine acid rocks, Kii Peninsula, were reported by KAWASAKI (1980).

Structural Formulas of the Analyzed Biotites

Calculation of Structural Formulas of the Analyzed Biotites

FOSTER (1960) reported chemical structural formulas calculated on the basis of the cationic and anionic valence contents of the idealzied unit cell, 44, for 204 trioctahedral micas, and discussed chemical features, classification and geologic occurrence of trioctahedral micas.

Following to FOSTER's calculation system, structural formulas of the analyzed

Table 1. Chemical Analyses of Biotites from Granitic Rocks of the Southwestern Outer Zone-type

Rock bodies	OS	"	"	"	"	"	"	"	"	"	"
Rocks	HBGD	"	"	"	PX	"	HBGD	"	"	"	"
Loc. or types	Manguro	"	Hedaokawa	"	Uchinoura	"	"	"	Koyama	"	Sata
Nos.	59080302	2D-17	59080403	5d-5	3-Xe	59082402	8041704	8042710	8031412	8031329	8050245
Anal.	N.O.	"	"	"	"	"	Y.Y.	T.H.	Y.I.	Y.Y.	T.N.
Methods	a	"	"	"	"	"	b	"	"	"	"
Coll.	N.O.	"	"	"	"	"	Y.Y.	T.H.	Y.I.	Y.Y.	T.N.
Ref.	(8)	"	"	"	*	*	(10)	(3)	(4)	(10)	(6)
SiO_2	33.12	34.26	34.96	35.87	33.97	33.46	34.30	34.32	33.02	33.36	34.48
TiO_2	3.32	1.80	3.40	1.27	3.68	2.40	4.32	4.72	4.88	4.84	4.05
Al_2O_3	13.87	17.31	13.31	17.58	15.74	20.04	15.97	14.71	14.27	15.62	14.87
Fe_2O_3	10.60	5.58	7.64	4.97	5.99	5.96	4.52	3.59	5.26	5.09	2.81
FeO	14.51	18.87	15.50	17.36	17.62	19.92	18.37	20.19	19.69	18.56	21.50
MnO	0.38	0.26	0.63	0.19	0.76	0.27	0.83	0.34	0.36	0.61	0.30
MgO	8.56	9.02	8.84	9.95	8.40	6.47	8.14	8.36	11.84	7.62	8.18
CaO	1.06	0.92	0.76	0.95	0.88	0.57	0.40	0.52	0.36	0.43	0.52
Na_2O	0.50	0.70	0.35	1.00	0.60	0.70	0.55	0.27	0.20	0.51	0.17
K_2O	5.10	6.90	6.00	7.35	6.40	6.90	8.04	8.16	8.75	7.59	7.23
H_2O+	7.40	3.93	6.36	3.23	4.79	3.20	4.08	4.49	3.80	3.84	4.70
H_2O-	1.95	0.56	1.67	0.62	1.00	0.82	1.04	1.38	1.32	1.24	0.28
P_2O_5	0.03	0.01	0.12	0.01	0.05	0.01	-	-	-	-	-
F	0.47	0.38	0.41	0.36	0.52	0.34	-	-	-	-	-
Cl	0.10	0.13	0.18	0.20	0.16	0.35	-	-	-	-	-
Total	100.97	100.63	100.13	100.91	100.56	101.41	100.56	101.05	100.02	99.31	99.09
O=F, Cl	0.22	0.19	0.12	0.20	0.25	0.22	-	-	-	-	-
Adjusted total	100.75	100.44	99.92	100.71	100.31	101.19	-	-	-	-	-

(continued)

Rock bodies	OS	"	S	"	"	"	"	"	"	"	OK
Rocks	HBGD	"	"	"	"	"	BX	HBGD	"	"	"
Loc. or types	Sata	Nejime	Kusubae	"	Hirabae	"	"	Kusubae	"	"	Main
Nos.	8050503	8041106	62122604	23	59102101	2101	2102-2	GD-1	GD-2	GD-3	1
Anal.	T.N.	"	N.O.	"	"	"	"	T.A.	"	"	Y.S.
Methods	b	"	a	"	"	"	"	"	"	"	"
Coll.	T.N.	"	N.O.	"	"	"	"	T.A.	"	"	Y.S.
Ref.	(6)	"	(8)	"	"	"	"	(1)	"	"	(5)
SiO_2	34.44	35.24	33.50	37.50	33.75	36.26	35.86	34.24	34.28	35.40	36.32
TiO_2	4.12	4.02	4.60	1.27	3.40	1.50	1.45	5.84	2.96	4.08	3.03
Al_2O_3	16.16	13.95	12.64	16.12	13.41	15.75	15.85	12.69	14.96	12.51	15.05
Fe_2O_3	2.44	2.20	10.41	6.34	8.39	5.58	5.03	1.71	1.46	1.91	0.87
FeO	20.86	20.29	16.75	20.85	16.29	22.82	21.93	25.21	24.64	25.14	18.61
MnO	0.36	0.34	0.52	0.25	0.42	0.23	0.35	0.47	0.47	0.36	0.25
MgO	8.16	9.22	7.03	7.00	7.15	7.41	8.48	7.70	8.22	7.46	9.91
CaO	0.40	0.82	1.10	1.29	1.05	0.62	0.81	1.00	0.88	1.83	0.93
Na_2O	0.17	0.15	0.40	0.60	0.40	0.90	0.60	0.32	0.32	0.32	0.80
K_2O	7.51	7.64	7.40	7.20	6.85	8.20	7.90	6.40	7.50	7.00	7.60
H_2O+	4.90	4.54	4.61	1.78	6.52	1.22	1.96	3.24	3.08	3.08	5.28
H_2O-	0.48	0.56	1.47	0.46	2.27	0.26	0.20	0.48	0.44	0.62	0.84
P_2O_5	-	-	0.21	0.01	0.15	0.02	0.01	tr.	0.02	tr.	0.03
F	-	-	0.56	0.44	0.61	0.58	0.37	-	-	-	-
Cl	-	-	0.33	0.10	0.44	0.38	0.28	-	-	-	-
Total	100.00	98.97	101.43	101.21	101.10	101.73	101.08	99.51	99.23	99.51	99.52
C=F, Cl	-	-	0.31	0.21	0.35	0.33	0.22	-	-	-	-
Adjusted total	-	-	101.12	101.00	100.75	101.40	100.86	-	-	-	-

(continued)

Rock bodies	OK	"	"	"	"	"	"	"	T	"	"	"
Rocks	HBGD	"	"	"	"	"	"	"	BG	"	"	"
Loc. or types	Main	"	"	Shishi-gawa	"	"	"	"	Shin-kōji	"	"	"
Nos.	3	6	B-3	Oks-1	Oks-2	Oks-3	Oks-4	Oks-5	103	TAKA 101	TAKA 102	TK21
Anal.	M.M.	A.O.	K.K.	T.O.	"	"	"	"	N.O.	H.Y.	"	M.Y.
Methods	a	"	"	"	"	"	"	"	"	"	"	"
Coll.	Y.S.	A.O.	K.K.	T.O.	"	"	"	"	N.O.	N.O.	"	M.Y.
Ref.	(5)	"	"	(7)	"	"	"	"	(8)	*	"	(9)
SiO_2	36.06	34.92	32.52	35.98	34.96	35.02	35.36	35.72	32.89	34.84	35.42	35.90
TiO_2	4.17	3.88	3.16	3.66	3.66	3.58	3.56	2.32	2.42	2.44	2.46	3.00
Al_2O_3	13.01	13.10	15.94	12.29	12.98	12.68	12.74	14.19	16.89	17.00	16.79	15.48
Fe_2O_3	2.91	3.73	8.86	4.36	4.98	5.56	5.73	3.48	9.46	1.17	4.33	3.56
FeO	21.79	21.15	18.84	20.48	19.22	19.31	19.94	22.82	12.95	19.34	19.29	18.82
MnO	0.26	0.20	0.30	0.35	0.29	0.30	0.29	0.75	0.81	0.28	0.10	0.27
MgO	7.75	7.26	6.01	7.24	7.66	8.31	8.30	5.91	7.33	7.89	8.70	9.60
CaO	1.16	0.83	0.10	1.26	1.03	0.50	0.41	0.35	0.55	0.42	0.54	1.24
Na_2O	0.60	1.25	0.54	0.30	0.50	0.20	0.30	0.70	0.40	1.20	0.50	0.30
K_2O	7.10	6.81	7.13	7.20	8.00	7.50	6.70	7.15	6.55	10.80	7.04	7.20
H_2O+	4.20	5.12	5.38	4.76	4.46	4.52	4.62	4.28	7.72	4.10	4.38	3.92
H_2O-	0.60	1.68	0.94	1.53	2.32	2.37	1.66	1.65	1.56	0.20	0.20	0.68
P_2O_5	0.01	0.06	0.03	0.04	0.01	0.02	0.03	0.09	0.03	0.05	0.05	0.02
F	-	-	-	-	-	-	-	-	0.55	-	-	-
Cl	-	-	-	-	-	-	-	-	0.14	-	-	-
Total	99.62	99.99	99.55	99.45	100.07	99.87	100.64	99.40	100.25	99.73	99.80	99.99
O=F, Cl	-	-	-	-	-	-	-	-	0.33	-	-	-
Adjusted total	-	-	-	-	-	-	-	-	99.96	-	-	-

(continued)

Rock bodies	T	"	"	"	"	"	"	"	"	"	"
Rocks	BG	"	"	AG	"	"	"	"	"	"	"
Loc. or types	Shin-kōji	Grada-tional	"	Saruga-jyō	"	"	"	"	"	"	"
Nos.	TK01	TK04	TK05	59080201	TAKA 105	TAKA 106	TAKA 107	TK06	TK07	TK08	TK09
Anal.	M.Y.	"	"	N.O.	H.Y.	"	"	M.Y.	"	J.O.& M.Y.	J.O.& H.Y.
Methods	a	"	"	"	"	"	"	"	"	"	"
Coll.	M.Y.	"	"	N.O.	N.O.	"	"	M.Y.	"	J.O.	"
Ref.	(9)	"	"	(8)	*	"	"	"	(9)	*	(9)
SiO_2	34.52	33.40	33.72	32.70	39.84	34.34	34.56	33.80	33.96	33.68	34.48
TiO_2	2.84	1.82	1.96	1.56	2.08	1.96	1.90	2.01	1.64	1.60	2.52
Al_2O_3	16.94	19.38	19.76	19.30	18.68	20.88	19.69	19.56	20.22	20.60	20.87
Fe_2O_3	4.19	4.84	4.48	13.03	1.54	2.89	3.53	5.10	6.79	5.86	4.85
FeO	18.52	20.72	19.76	9.67	20.30	22.07	21.15	20.92	18.76	19.34	19.88
MnO	0.41	0.82	0.68	1.62	0.83	0.62	0.82	0.50	0.84	0.86	0.52
MgO	9.12	5.20	5.43	2.69	4.60	3.32	4.47	3.38	3.28	3.58	3.03
CaO	0.60	0.74	0.45	0.32	0.57	1.76	0.48	0.56	0.67	0.40	0.69
Na_2O	0.40	0.48	0.26	0.50	0.45	0.40	0.34	0.28	0.28	0.34	0.24
K_2O	7.60	7.00	7.08	7.40	6.50	6.36	7.22	7.02	7.00	7.44	7.60
H_2O+	3.76	5.12	5.36	8.74	4.84	4.98	4.48	5.12	4.78	5.08	4.54
H_2O-	0.72	0.24	0.92	2.89	0.64	0.42	0.52	1.36	1.52	0.96	0.79
P_2O_5	0.10	0.08	0.05	0.02	0.07	0.05	0.04	0.04	0.02	0.01	0.01
F	-	-	-	1.15	-	-	-	-	-	-	-
Cl	-	-	-	0.10	-	-	-	-	-	-	-
Total	99.72	99.84	99.91	101.62	100.94	100.05	99.20	99.65	99.76	99.75	100.02
O=F, Cl	-	-	-	0.50	-	-	-	-	-	-	-
Adjusted total	-	-	-	101.12	-	-	-	-	-	-	-

(continued)

Rock bodies	T	Y	"	"	"	"	"	OB	U	"	A
Rocks	AG	BG	"	"	"	"	"	"	HBGD	"	"
Loc. or types	Saruga-jyō	Miyano-ura	Anbō	Onoaida	Nakama	Nagata	Issō		Yakushi-dani	Nametoko	Ashizuri
Nos.	TK10	Y 1	Y 2	Y 4	Y 5	Y 6	Y 7	2	Uwajima 1	Uwajima 3	Ashizuri 1
Anal.	H.Y.	T.HA.	"	"	"	"	"	K.K.	H.Y.	"	"
Methods	a	"	"	"	"	"	"	"	"	"	"
Coll.	J.O.	T.HA.	"	"	"	"	"	K.K.	K.H.	"	H.S.
Ref.	*	(2)	"	"	"	"	"	(5)	*	"	"
SiO_2	33.68	37.68	35.62	34.72	34.78	34.42	34.40	32.52	41.52	37.06	35.48
TiO_2	2.20	3.45	3.40	3.40	3.46	3.34	3.28	3.16	3.76	3.76	3.18
Al_2O_3	20.22	15.87	18.50	16.97	16.63	16.76	16.31	15.94	11.47	13.78	14.79
Fe_2O_3	6.76	5.11	3.97	5.83	6.74	8.01	8.24	8.86	0.38	0.41	6.47
FeO	18.08	17.70	17.96	17.89	17.14	14.92	14.85	18.84	19.74	21.86	22.04
MnO	0.88	0.33	0.57	0.24	0.22	0.40	0.28	0.30	0.16	0.18	0.31
MgO	2.93	6.82	6.89	6.78	6.83	6.77	6.75	6.01	11.11	10.70	5.34
CaO	1.04	0.48	0.33	0.42	0.45	0.39	0.25	0.10	1.16	0.18	2.47
Na_2O	0.44	0.30	0.01	0.40	0.40	0.50	0.40	0.54	0.30	0.50	1.10
K_2O	7.60	7.00	6.60	8.30	7.40	7.20	7.50	7.13	6.40	8.26	4.10
H_2O+	3.50	4.10	4.84	4.52	4.96	6.14	6.16	5.38	4.20	3.24	3.64
H_2O-	1.98	1.42	1.78	0.82	1.00	1.58	1.64	0.94	0.52	0.32	0.36
P_2O_5	0.01	tr.	0.01	tr.	tr.	tr.	tr.	0.03	0.27	0.12	0.14
F	-	-	-	-	-	-	-	-	-	-	-
Cl	-	-	-	-	-	-	-	-	-	-	-
Total	99.32	100.26	100.48	100.29	100.01	100.43	100.06	99.55	100.99	100.37	99.42
C=F, Cl	-	-	-	-	-	-	-	-	-	-	-
Adjusted total	-	-	-	-	-	-	-	-	-	-	-

Note. Analytical methods: a, SiO_2 and $H_2O\pm$ were determined gravimetrically, TiO_2 and P_2O_5 colorimetrically, FeO by dichromate titration and other oxides by the ion exchange resin and chlete titration; b, $SiO_2 \cdot H_2O\pm \cdot TiO_2 \cdot P_2O_5$ and FeO were determined by the same method as a, and other oxides by atomic absorption. F and Cl were analysed by N. SHIMODA. * New analyses. – Not done.

Abbreviations. – Rock bodies: OS: Ōsumi; S: Shibisan; OK: Ōkeyama; T: Takakumayama; Y: Yakujima; OB: Obira; U: Uwajima; A: Ashizuri. Rocks: HBGD: Hornblende biotite granodiorite~adamellite; BG: Biotite granite, AG: Aplogranite; GP: Granite porphyry; PX: Pelitic xenolith; BX: Basic xenolith. Analysts and collectors: T.A.: T. ADACHI; H.H.: H. HIGASHIHAMA; K.H.: K. HORIKOSHI; T.H.: T. HAYASHI; T. HA.: T. HARADA; Y.I.: Y. IKEDA; K.K.: K. KATAYAMA; M.M.: M. MURATA; T.N.: T. NAKAMURA; A.O.: A. ONZA; J.O.: J. OGURA; N.O.: N. ŌBA; T.O.: T. OBA; H.S.: H. SHIBATA; Y.S.: Y. SUKESHITA; H.Y. H. YAMASHITA; M.Y.: M. YAMAMOTO; Y.Y.: Y. YAMAUCHI; H. YA.: H. YAMAGUCHI. References: (1) ADACHI (1973); (2) HARADA (1970); (3) HAYASHI (1978); (4) IKEDA (1978); (5) MURATA (1976); (6) NAKAMURA (1978); (7) OBA and others (1977); (8) SHIBATA and others (1966); (9) YAMAMOTO (1978); (10) YAMAUCHI (1978).

biotites were calculated to the idealized formula of trioctahedral mica, $X_2Y_6Z_8O_{20}(OH)_4$ in the unit cell. Data used for writing the structural formulas are shown in table 2. The structural formulas expressed in a half-cell of the analyzed biotites are given in table 3. As tables 2 and 3 show, the electric charge between the cationic valence content and the anionic valence content is considerably well balanced, except for some biotites.

Location of the Analyzed Biotites on the Foster's Triangular Diagram Mg, R^{3+} and Fe^{2+}

Plotting the analyzed biotites on the FOSTER's triangular diagram (fig. 1) showing the relative quantitative relation between Mg, R^{3+} (Al^{VI}, Fe^{3+} and Ti) and Fe^{2+} (Mn^{2+}) in octahedral layers, on that which the points representing the so-called biotites fall between 20–60% for Mg in the occupied octahedral positions and the points representing Fe^{2+}-dominant biotites occupy the lower half of the biotite area lower than 40% for Mg, most of the analyzed biotites fall within the bivalent iron-dominant biotite area.

With respect to the number of additional positive octahedral charge in the octahedral layers of biotite structural formulas, FOSTER (1960) pointed out that most biotites having the number of additional positive charge greater than 0.5 in the unit cell or 0.25 in the half-cell belong to the bivalent iron-dominant biotite. As seen from talbes 2 and 3, thirty four analyzed biotites among fifty six ones have the number of additional positive charge greater than 0.50 in the unit cell or 0.25 in the half-cell in the octahedral layers.

X-ray Powder Diffraction of the Analyzed Biotites and Estimated Polymorphs

X-ray powder diffraction employing CuKα radiation was made of the analyzed biotites to examine polymorph of the biotites from granitic rocks belonging to the same genetical system, i.e., the Southwestern Outer Zone-type, and to investigate a relation between chemical composition and polymorph of the biotites, a relation betwen polymorph of the biotites and chemical composition of its host granitic rocks, and the reflection of the remarkable contamination by which granitic rocks were affected to polymorph of the analyzed biotites. However, almost all of these subjects could not be dissolved on the following reason.

Although the standard X-ray powder patterns for various polymorphs of biotite should be established, they have not yet been settled. Accordingly, it has been difficult to identify individual polymorphs from X-ray powder data only. According to SMITH and YODER (1958), only common polymorphs such as dioctahedral 1M–3T and 2M polymorphs can be identified from powder patterns, but 1M polymorph and 3T polymorph in phlogopite and other trioctahedral micas can only be distinguished from each other by using a single crystal method. Regarding synthetic annite, X-ray data

Table 2. Data Used For Writing Structural Formulas of Analyzed Biotites on the Basis of the Valence Content of the Idealized Unit Cell=44.00

Rock bodies		OS	"	"	"	"	"	"	"	"	"
Nos.		59080302	2D-17	59080403	5d-5	3-Xe	59082402	8041704	8042710	8031412	8031329
Ref. or calc.		N.O.	"	"	"	"	"	(10)	(3)	(4)	(10)
	Si	5.29	5.25	5.55	5.39	5.28	5.08	5.27	5.27	5.01	5.25
Tetrahedral	Al^{IV}	2.61	2.75	2.46	2.61	2.72	2.92	2.73	2.66	2.55	2.75
positions	Ti	0.10	-	-	-	-	-	-	0.07	0.44	-
	Fe^{3+}	-	-	-	-	-	-	-	-	-	-
	Total	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
	Al^{VI}	-	0.37	0.03	0.50	0.17	0.67	0.16	-	-	0.15
	Ti	0.30	0.21	0.41	0.14	0.43	0.27	0.50	0.48	0.12	0.57
Octahedral	Fe^{3+}	1.27	0.64	0.91	0.56	0.70	0.68	0.52	0.42	0.60	0.52
positions	Fe^{2+}	1.94	2.42	2.05	2.18	2.29	2.53	2.36	2.59	2.50	2.44
	Mg	2.04	2.06	2.09	2.23	1.95	1.46	1.86	1.91	2.68	1.79
	Mn	0.05	0.03	0.09	0.02	0.10	0.04	0.11	0.04	0.05	0.08
	Total	5.60	5.73	5.58	5.63	5.64	5.65	5.51	5.44	5.95	5.55
	Ca	0.18	0.15	0.13	0.15	0.15	0.09	0.07	0.09	0.10	0.07
Interlayer	Na	0.15	0.21	0.11	0.29	0.18	0.21	0.16	0.08	0.06	0.16
positions	K	1.04	1.34	1.21	1.41	1.27	1.33	1.57	1.60	1.70	1.52
	Total	1.37	1.70	1.45	1.85	1.60	1.63	1.80	1.77	1.86	1.75
Octahedral charge		+1.05	+0.89	+0.89	+0.61	+0.98	+1.18	+0.70	+0.26	+0.74	+0.91
Tetrahedral charge		-2.61	-2.75	-2.46	-2.61	-2.72	-2.92	-2.73	-2.66	-2.55	-2.75
Inherent layer charge		-1.56	-1.86	-1.57	-2.00	-1.74	-1.74	-2.03	-2.40	-1.81	-1.84
Interlayer charge		+1.55	+1.86	+1.57	+2.00	+1.59	+1.72	+1.87	+1.86	+1.96	+1.82

Abbreviations and number of samples and references correspond to those in table 1.

(continued)

Rock bodies		OS	"	"	S	"	"	"	"	"	"	"
Nos.		8050245	8050503	8041106	62122604	23	59102101	2101	2102-2	GD-1	GD-2	GD-3
Ref. or calc.		(6)	"	"	N.O.	"	"	"	"	"	"	"
	Si	5.31	5.23	5.43	5.29	5.61	5.45	5.47	5.43	5.38	5.39	5.56
Tetrahedral	Al^{IV}	2.69	2.77	2.53	2.35	2.39	2.55	2.53	2.67	2.35	2.61	2.31
positions	Ti	-	-	0.04	0.35	-	-	-	-	0.27	-	0.13
	Fe^{3+}	-	-	-	-	-	-	-	-	-	-	-
	Total	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
	Al^{VI}	tr.	0.12	-	-	0.45	0.01	0.26	0.16	-	0.16	-
	Ti	0.47	0.47	0.43	0.19	0.14	0.41	0.17	0.17	0.42	0.35	0.35
Octahedral	Fe^{3+}	0.33	0.28	0.26	1.24	0.71	1.02	0.63	0.57	0.20	0.17	0.23
positions	Fe^{2+}	2.77	2.65	2.62	2.21	2.60	2.20	2.87	2.77	3.31	3.24	3.30
	Mg	1.88	1.85	2.12	1.66	1.56	1.72	1.67	1.91	1.80	1.92	1.75
	Mn	0.04	0.05	0.05	0.07	0.03	0.06	0.03	0.05	0.06	0.06	0.05
	Total	5.49	5.42	5.48	5.37	5.49	5.42	5.63	5.63	5.79	5.90	5.68
	Ca	0.09	0.07	0.14	0.19	0.21	0.18	0.10	0.13	0.17	0.15	0.31
Interlayer	Na	0.50	0.05	0.05	0.12	0.17	0.13	0.26	0.17	0.09	0.09	0.09
positions	K	1.42	1.45	1.50	1.49	1.37	1.41	1.58	1.53	1.28	1.50	1.41
	Total	2.01	1.57	1.69	1.80	1.75	1.72	1.94	1.83	1.54	1.74	1.81
Octahedral charge		+0.25	+0.18	+0.08	+0.36	+0.43	+0.67	+0.50	+0.32	+0.63	+0.84	+0.27
Tetrahedral charge		-2.69	-2.77	-2.53	-2.35	-2.39	-2.55	-2.53	-2.67	-2.35	-2.61	-2.31
Inherent layer charge		-2.44	-2.59	-2.45	-1.99	-1.96	-1.88	-2.04	-2.35	-1.72	-1.77	-2.04
Interlayer charge		+2.10	+1.64	+1.83	+1.99	+1.96	+1.89	+2.04	+1.96	+1.72	+1.89	+2.11

(continued)

Rock bodies		OK	"	"	"	"	"	"	"	"	T	"	"
Nos.		1	3	6	B-3	Oks-1	Oks-2	Oks-3	Oks-4	Oks-5	103	TAKA 101	TAKA 102
Ref. or calc.		(5)	"	"	N.O.	"	"	"	"	"	"	H.Y.	"
	Si	5.58	5.62	5.56	5.18	5.71	5.55	5.55	5.61	5.67	4.87	5.42	5.42
Tetrahedral	Al^{IV}	2.42	2.38	2.45	2.82	2.29	2.43	2.37	2.38	2.33	2.94	2.58	2.58
positions	Ti	-	-	-	-	-	0.02	0.08	0.01	-	0.19	-	-
	Fe^{3+}	-	-	-	-	-	-	-	-	-	-	-	-
	Total	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
	Al^{VI}	0.30	0.02	0.03	0.17	0.01	-	-	-	0.32	-	0.54	0.46
	Ti	0.35	0.49	0.46	0.38	0.44	0.42	0.35	0.41	0.28	0.08	0.28	0.28
Octahedral	Fe^{3+}	tr.	0.34	0.45	1.06	0.52	0.59	0.66	0.68	0.42	2.16	0.14	0.50
positions	Fe^{2+}	2.39	2.86	2.81	2.51	2.71	2.55	2.56	2.64	3.02	1.60	2.52	2.46
	Mg	2.27	1.78	1.72	1.43	1.71	1.81	1.96	1.96	1.40	1.62	1.82	1.98
	Mn	0.03	0.05	0.03	0.04	0.05	0.04	0.04	0.04	0.10	0.10	0.04	0.02
	Total	5.34	5.54	5.50	5.59	5.44	5.41	5.57	5.73	5.54	5.56	5.34	5.70
	Ca	0.15	0.19	0.14	0.02	0.21	0.18	0.09	0.07	0.06	0.09	0.08	0.08
Interlayer	Na	0.24	0.19	0.39	0.16	0.10	0.15	0.06	0.10	0.22	0.12	0.36	0.14
positions	K	2.19	1.40	1.38	1.45	1.46	1.62	1.51	1.35	1.45	1.23	2.14	1.38
	Total	2.58	1.78	1.91	1.63	1.77	1.95	1.66	1.52	1.73	1.44	2.58	1.60
Octahedral charge		-0.32	+0.42	+0.40	+1.15	+0.28	+0.25	+0.50	+0.97	+0.35	+1.43	-0.08	+0.92
Tetrahedral charge		-2.42	-2.38	-2.45	-2.82	-2.29	-2.43	-2.37	-2.38	-2.33	-2.94	-2.58	-2.58
Inherent layer charge		-2.74	-1.96	-2.05	-1.67	-2.01	-2.18	-1.87	-1.41	-1.98	-1.51	-2.66	-1.66
Interlayer charge		+2.73	+1.97	+2.05	+1.65	+1.98	+2.12	+1.74	+1.59	+1.78	+1.53	+2.66	+1.68

(continued)

Rock bodies		T	"	"	"	"	"	"	"	"	"
Nos.		TK21	TK01	TK04	TK05	59080201	TAKA 105	TAKA 106	TAKA 107	TK06	TK07
Ref. or calc.		(9)	"	"	"	N.O.	H.Y.	"	"	M.Y.	(9)
	Si	5.475	5.314	5.081	5.096	5.31	5.96	5.32	5.38	5.184	5.208
Tetrahedral	Al^{IV}	2.525	2.686	2.919	2.904	2.69	2.06	2.68	2.62	2.816	2.792
positions	Ti	-	-	-	-	-	-	-	-	-	-
	Fe^{3+}	-	-	-	-	-	-	-	-	-	-
	Total	8.000	8.000	8.000	8.000	8.00	8.00	8.00	8.00	8.000	8.000
	Al^{VI}	0.263	0.387	0.554	0.621	0.67	1.24	1.14	1.00	0.726	0.858
	Ti	0.348	0.333	0.210	0.227	0.19	0.24	0.22	0.22	0.231	0.194
Octahedral	Fe^{3+}	0.404	0.481	0.548	0.509	1.59	0.18	0.34	0.42	0.590	0.793
positions	Fe^{2+}	2.403	2.388	2.632	2.498	1.31	2.54	2.86	2.76	2.684	2.406
	Mg	2.183	2.092	1.179	1.226	0.65	1.02	0.76	1.04	0.775	0.747
	Mn	0.037	0.056	0.110	0.091	0.22	0.10	0.08	0.10	0.065	0.111
	Total	5.638	5.737	5.233	5.172	4.63	5.32	5.40	5.54	5.071	5.109
	Ca	0.202	0.102	0.119	0.073	0.05	0.10	0.30	0.08	0.092	0.111
Interlayer	Na	0.092	0.111	0.146	0.073	0.16	0.14	0.12	0.10	0.092	0.074
positions	K	1.394	1.500	1.353	1.363	1.55	1.24	1.26	1.44	1.384	1.364
	Total	1.688	1.713	1.618	1.509	1.76	1.48	1.68	1.62	1.568	1.549
Octahedral charge		+0.639	+1.008	-0.012	-0.072	-0.11	+0.54	+0.72	+0.94	-0.080	+0.257
Tetrahedral charge		-2.525	-2.686	-2.919	-2.904	-2.69	-2.06	-2.68	-2.62	-2.816	-2.792
Inherent layer charge		-1.886	-1.678	-2.931	-2.976	-2.80	-1.52	-1.96	-1.68	-2.896	-2.535
Interlayer charge		+1.890	+1.815	+1.737	+1.582	+1.81	+1.58	+1.98	+1.70	+1.660	+1.660

(continued)

Rock bodies		"	"	"	Y	"	"	"	"	"	OB	U
Nos.		TK08	TK09	TK10	Y 1	Y 2	Y 4	Y 5	Y 6	Y 7	2	Uwajima 1
Ref. or calc.		J.O.	(9)	J.O.	(2)	"	"	"	"	"	(5)	H.Y.
Tetrahedral positions	Si	5.130	5.248	5.304	5.72	5.50	5.36	5.39	5.38	5.41	5.17	6.16
	Al^{IV}	2.870	2.752	2.696	2.28	2.50	2.64	2.61	2.62	2.59	2.83	1.84
	Ti	-	-	-	-	-	-	-	-	-	-	-
	Fe^{3+}	-	-	-	-	-	-	-	-	-	-	-
	Total	8.000	8.000	8.000	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Octahedral positions	Al^{VI}	0.831	0.997	1.055	0.56	0.87	0.45	0.42	0.46	0.43	0.17	0.16
	Ti	0.183	0.293	0.265	0.39	0.28	0.39	0.40	0.39	0.39	0.38	0.42
	Fe^{3+}	0.678	0.549	0.796	0.58	0.46	0.68	0.78	0.94	0.98	1.07	0.04
	Fe^{2+}	2.464	2.533	2.387	2.25	2.32	2.31	2.22	1.95	1.98	2.51	2.46
	Mg	0.815	0.686	0.691	1.54	1.59	1.56	1.58	1.58	1.58	1.44	2.46
	Mn	0.110	0.064	0.114	0.04	0.07	0.03	0.03	0.05	0.04	0.17	0.02
	Total	5.081	5.122	5.308	5.36	5.59	5.42	5.43	5.37	5.40	5.74	5.52
Interlayer positions	Ca	0.064	0.111	0.180	0.08	0.06	0.07	0.08	0.07	0.04	0.02	0.20
	Na	0.092	0.073	0.133	0.09	0.04	0.12	0.12	0.15	0.12	0.16	0.10
	K	1.447	1.481	1.534	1.36	1.30	1.63	1.46	1.44	1.50	1.45	1.22
	Total	1.603	1.664	1.847	1.53	1.40	1.82	1.66	1.66	1.66	1.63	1.52
Octahedral charge		+0.037	+0.376	+0.997	+0.64	+1.07	+0.75	+0.86	+0.92	+0.99	+1.48	+0.16
Tetrahedral charge		-2.870	-2.752	-2.696	-2.28	-2.50	-2.64	-2.61	-2.62	-2.59	-2.83	-1.84
Inherent layer charge		-2.833	-2.376	-1.699	-1.64	-1.43	-1.89	-1.75	-1.70	-1.60	-1.35	-1.68
Interlayer charge		+1.667	+1.776	+2.027	+1.61	+1.46	+1.89	+1.74	+1.73	+1.70	+1.65	+1.72

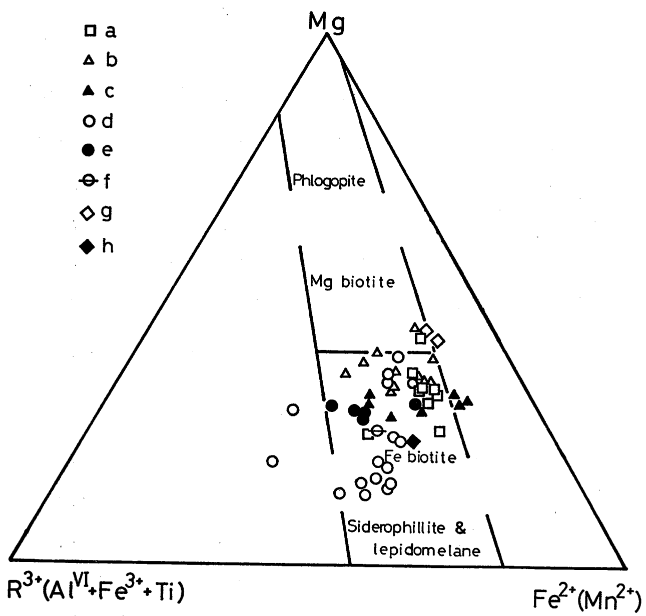

Fig. 1. Locations of analyzed biotites from granitic rocks of the Southwestern Outer Zone-type on Foster's (1960) triangular diagram showing the relative quantitative relation between Mg, R^{3+} (Al^{VI}, Fe^{3+} and Ti) and Fe^{2+} (Mn^{2+}) in octahedral layers. Symbols of rock bodies of analyzed biotites: a, Ōkueyama; b, Ōsumi; c, Shibisan; d, Takakumayama; e, Yakujima; f, Obira; g, Uwajima; h, Ashizuri.

(continued)

Rock bodies		U	A
Nos.		Uwajima 3	Ashizuri 1
Ref. or calc.		H.Y.	"
	Si	5.64	5.50
Tetrahedral	Al^{IV}	2.36	2.50
positions	Ti	-	-
	Fe^{3+}	-	-
	Total	8.00	8.00
	Al^{VI}	0.10	0.18
	Ti	0.44	0.38
Octahedral	Fe^{3+}	0.04	0.76
positions	Fe^{2+}	2.78	2.86
	Mg	2.42	1.24
	Mn	0.02	0.04
	Total	5.80	5.46
	Ca	0.02	0.40
Interlayer	Na	0.14	0.32
positions	K	1.60	0.82
	Total	1.76	1.54
Octahedral charge		+0.62	+0.62
Tetrahedral charge		-2.36	-2.50
Inherent layer charge		-1.74	-1.88
Interlayer charge		+1.78	+1.94

Table 3. Structural Formulas (Half Cell) of Biotites from Granitic rocks of the Southwestern Outer zone-Type

Rock bodies	Nos.	Ref. or calc.	Structural formulas
OS	59080302	N.O.	$[\underbrace{\overset{+0.56}{(Ti_{0.15}Fe^{3+}_{0.64}Fe^{2+}_{0.97}Mg_{1.02}Mn_{0.03})}}_{2.81}\overset{-1.30}{(Si_{2.65}Al^{iv}_{1.30}Ti_{0.05})}O_{10}(OH)_2]^{-0.74}(K_{0.52}Na_{0.08}Ca_{0.09})^{+0.78}_{0.69}$
"	2D-17	"	$[\underbrace{\overset{+0.41}{(Al^{vi}_{0.19}Ti_{0.10}Fe^{3+}_{0.32}Fe^{2+}_{1.21}Mg_{1.03}Mn_{0.02})}}_{2.87}\overset{-1.38}{(Si_{2.62}Al^{iv}_{1.38})}O_{10}(OH)_2]^{-0.97}(K_{0.67}Na_{0.11}Ca_{0.08})^{+0.94}_{0.86}$
"	59080403	"	$[\underbrace{\overset{+0.48}{(Al^{vi}_{0.02}Ti_{0.20}Fe^{3+}_{0.46}Fe^{2+}_{1.03}Mg_{1.05}Mn_{0.04})}}_{2.80}\overset{-1.23}{(Si_{2.77}Al^{iv}_{1.23})}O_{10}(OH)_2]^{-0.75}(K_{0.60}Na_{0.05}Ca_{0.06})^{+0.77}_{0.71}$
"	5d-5	"	$[\underbrace{\overset{+0.29}{(Al^{vi}_{0.25}Ti_{0.07}Fe^{3+}_{0.28}Fe^{2+}_{1.09}Mg_{1.11}Mn_{0.01})}}_{2.81}\overset{-1.31}{(Si_{2.69}Al^{iv}_{1.31})}O_{10}(OH)_2]^{-1.02}(K_{0.70}Na_{0.14}Ca_{0.08})^{+1.00}_{0.92}$
"	3-Xe	"	$[\underbrace{\overset{+0.49}{(Al^{vi}_{0.08}Ti_{0.22}Fe^{3+}_{0.35}Fe^{2+}_{1.14}Mg_{0.97}Mn_{0.05})}}_{2.81}\overset{-1.36}{(Si_{2.64}Al^{iv}_{1.36})}O_{10}(OH)_2]^{-0.87}(K_{0.64}Na_{0.09}Ca_{0.07})^{+0.87}_{0.80}$
"	59082402	"	$[\underbrace{\overset{+0.59}{(Al^{vi}_{0.33}Ti_{0.14}Fe^{3+}_{0.34}Fe^{2+}_{1.26}Mg_{0.73}Mn_{0.02})}}_{2.82}\overset{-1.46}{(Si_{2.54}Al^{iv}_{1.46})}O_{10}(OH)_2]^{-0.87}(K_{0.67}Na_{0.11}Ca_{0.05})^{+0.88}_{0.83}$
"	8041704	"	$[\underbrace{\overset{+0.56}{(Al^{vi}_{0.08}Ti_{0.25}Fe^{3+}_{0.26}Fe^{2+}_{1.18}Mg_{0.93}Mn_{0.06})}}_{2.76}\overset{-1.37}{(Si_{2.64}Al^{iv}_{1.37})}O_{10}(OH)_2]^{-0.81}(K_{0.79}Na_{0.08}Ca_{0.04})^{+0.95}_{0.91}$
"	8042710	"	$[\underbrace{\overset{+0.15}{(Ti_{0.24}Fe^{3+}_{0.21}Fe^{2+}_{1.30}Mg_{0.96}Mn_{0.02})}}_{2.73}\overset{-1.33}{(Si_{2.64}Al^{iv}_{1.33}Ti_{0.04})}O_{10}(OH)_2]^{-1.18}(K_{0.80}Na_{0.04}Ca_{0.05})^{+0.94}_{0.89}$
"	8031412	"	$[\underbrace{\overset{+0.38}{(Ti_{0.06}Fe^{3+}_{0.30}Fe^{2+}_{1.25}Mg_{1.34}Mn_{0.03})}}_{2.98}\overset{-1.28}{(Si_{2.51}Al^{iv}_{1.28}Ti_{0.22})}O_{10}(OH)_2]^{-0.90}(K_{0.85}Na_{0.03}Ca_{0.05})^{+0.98}_{0.93}$

Note. Abbreviations and number of samples and references correspond to those in table 1.

Rock bodies	Nos.	Ref. or calc.	Structural formulas
OS	8031329	N.O.	$[(\underbrace{Al^{vi}_{0.08}Ti_{0.29}Fe^{3+}_{0.26}Fe^{2+}_{1.22}Mg_{0.90}Mn_{0.04}}_{2.79})^{+0.50}(Si_{2.63}Al^{iv}_{1.38})^{-1.38}O_{10}(OH)_2]^{-0.88}(K_{0.76}Na_{0.08}Ca_{0.04})^{+0.92}_{0.88}$
"	8050245	"	$[(\underbrace{Ti_{0.24}Fe^{3+}_{0.17}Fe^{2+}_{1.39}Mg_{0.94}Mn_{0.02}}_{2.76})^{+0.17}(Si_{2.66}Al^{iv}_{1.35})^{-1.35}O_{10}(OH)_2]^{-1.18}(K_{0.71}Na_{0.25}Ca_{0.05})^{+1.06}_{1.01}$
"	8050503	"	$[(\underbrace{Al^{vi}_{0.06}Ti_{0.24}Fe^{3+}_{0.14}Fe^{2+}_{1.33}Mg_{0.93}Mn_{0.03}}_{2.73})^{+0.14}(Si_{2.62}Al^{iv}_{1.39})^{-1.39}O_{10}(OH)_2]^{-1.25}(K_{0.73}Na_{0.03}Ca_{0.04})^{+0.84}_{0.80}$
"	8041106	"	$[(\underbrace{Ti_{0.22}Fe^{3+}_{0.13}Fe^{2+}_{1.31}Mg_{1.06}Mn_{0.03}}_{2.75})^{+0.07}(Si_{2.72}Al^{iv}_{1.27}Ti_{0.02})^{-1.27}O_{10}(OH)_2]^{-1.20}(K_{0.75}Na_{0.03}Ca_{0.07})^{+0.92}_{0.85}$
S	62122604	"	$[(\underbrace{Ti_{0.10}Fe^{3+}_{0.62}Fe^{2+}_{1.11}Mg_{0.83}Mn_{0.04}}_{2.70})^{+0.22}(Si_{2.65}Al^{iv}_{1.18}Ti_{0.18})^{-1.18}O_{10}(OH)_2]^{-0.96}(K_{0.75}Na_{0.06}Ca_{0.09})^{+0.99}_{0.90}$
"	23	"	$[(\underbrace{Al^{vi}_{0.22}Ti_{0.07}Fe^{3+}_{0.36}Fe^{2+}_{1.30}Mg_{0.78}Mn_{0.02}}_{2.75})^{+0.22}(Si_{2.80}Al^{iv}_{1.20})^{-1.20}O_{10}(OH)_2]^{-0.98}(K_{0.69}Na_{0.09}Ca_{0.10})^{+0.98}_{0.88}$
"	59102101	"	$[(\underbrace{Al^{vi}_{0.01}Ti_{0.21}Fe^{3+}_{0.51}Fe^{2+}_{1.10}Mg_{0.86}Mn_{0.03}}_{2.72})^{+0.38}(Si_{2.73}Al^{iv}_{1.27})^{-1.27}O_{10}(OH)_2]^{-0.89}(K_{0.70}Na_{0.06}Ca_{0.09})^{+0.94}_{0.85}$
"	2101	"	$[(\underbrace{Al^{vi}_{0.13}Ti_{0.09}Fe^{3+}_{0.32}Fe^{2+}_{1.44}Mg_{0.83}Mn_{0.01}}_{2.82})^{+0.27}(Si_{2.73}Al^{iv}_{1.27})^{-1.27}O_{10}(OH)_2]^{-1.00}(K_{0.79}Na_{0.13}Ca_{0.05})^{+1.02}_{0.97}$
"	2102-2	"	$[(\underbrace{Al^{vi}_{0.08}Ti_{0.08}Fe^{3+}_{0.29}Fe^{2+}_{1.39}Mg_{0.96}Mn_{0.02}}_{2.82})^{+0.17}(Si_{2.72}Al^{iv}_{1.34})^{-1.34}O_{10}(OH)_2]^{-1.17}(K_{0.76}Na_{0.09}Ca_{0.07})^{+0.99}_{0.92}$

Rock Bodies	Nos.	Ref. or calc.	Structural formulas
S	GD-1	(1)	$[\overset{+0.32}{\underbrace{(Ti_{0.21}Fe^{3+}_{0.10}Fe^{2+}_{1.66}Mg_{0.90}Mn_{0.03})}_{2.90}}\overset{-1.18}{(Si_{2.69}Al^{iv}_{1.18}Ti_{0.14})}O_{10}(OH)_2]^{-0.86}(K_{0.64}Na_{0.05}Ca_{0.09})^{+0.87}_{0.78}$
"	GD-2	"	$[\overset{+0.45}{\underbrace{(Al^{vi}_{0.08}Ti_{0.18}Fe^{3+}_{0.09}Fe^{2+}_{1.62}Mg_{0.96}Mn_{0.03})}_{2.96}}\overset{-1.31}{(Si_{2.70}Al^{iv}_{1.31})}O_{10}(OH)_2]^{-0.86}(K_{0.75}Na_{0.05}Ca_{0.08})^{+0.96}_{0.88}$
"	GD-3	"	$[\overset{+0.20}{\underbrace{(Ti_{0.18}Fe^{3+}_{0.12}Fe^{2+}_{1.65}Mg_{0.88}Mn_{0.03})}_{2.86}}\overset{-1.16}{(Si_{2.78}Al^{iv}_{1.16}Ti_{0.07})}O_{10}(OH)_2]^{-0.96}(K_{0.71}Na_{0.05}Ca_{0.16})^{+1.08}_{0.92}$
OK	1	(5)	$[\overset{+0.17}{\underbrace{(Al^{vi}_{0.18}Ti_{0.18}Fe^{3+}_{0.05}Fe^{2+}_{1.21}Mg_{1.14}Mn_{0.03})}_{2.79}}\overset{-1.20}{(Si_{2.80}Al^{iv}_{1.20})}O_{10}(OH)_2]^{-1.03}(K_{0.74}Na_{0.14}Ca_{0.07})^{+1.02}_{0.95}$
"	3	"	$[\overset{+0.24}{\underbrace{(Al^{vi}_{0.01}Ti_{0.25}Fe^{3+}_{0.17}Fe^{2+}_{1.43}Mg_{0.89}Mn_{0.03})}_{2.78}}\overset{-1.19}{(Si_{2.81}Al^{iv}_{1.19})}O_{10}(OH)_2]^{-0.95}(K_{0.70}Na_{0.10}Ca_{0.10})^{+1.00}_{0.90}$
"	6	"	$[\overset{+0.25}{\underbrace{(Al^{vi}_{0.02}Ti_{0.23}Fe^{3+}_{0.22}Fe^{2+}_{1.41}Mg_{0.86}Mn_{0.01})}_{2.75}}\overset{-1.22}{(Si_{2.78}Al^{iv}_{1.22})}O_{10}(OH)_2]^{-0.97}(K_{0.69}Na_{0.19}Ca_{0.07})^{+1.02}_{0.95}$
"	B-3	"	$[\overset{+0.62}{\underbrace{(Al^{vi}_{0.09}Ti_{0.19}Fe^{3+}_{0.53}Fe^{2+}_{1.26}Mg_{0.72}Mn_{0.02})}_{2.81}}\overset{-1.41}{(Si_{2.58}Al^{iv}_{1.41})}O_{10}(OH)_2]^{-0.79}(K_{0.73}Na_{0.08}Ca_{0.01})^{+0.83}_{0.82}$
"	Oks-1	N.O.	$[\overset{+0.19}{\underbrace{(Al^{vi}_{0.01}Ti_{0.22}Fe^{3+}_{0.26}Fe^{2+}_{1.36}Mg_{0.86}Mn_{0.03})}_{2.74}}\overset{-1.15}{(Si_{2.36}Al^{iv}_{1.15})}C_{10}(OH)_2]^{-0.96}(K_{1.23}Na_{0.05}Ca_{0.11})^{+1.50}_{1.39}$
"	Oks-2	"	$[\overset{+0.16}{\underbrace{(Ti_{0.21}Fe^{3+}_{0.30}Fe^{2+}_{1.28}Mg_{0.91}Mn_{0.02})}_{2.72}}\overset{-1.22}{(Si_{2.78}Al^{iv}_{1.22}Ti_{0.01})}O_{10}(OH)_2]^{-1.06}(K_{0.81}Na_{0.08}Ca_{0.09})^{+1.07}_{0.98}$

Rock bodies	Nos.	Ref. or calc.	Structural formulas
OK	Oks-3	N.O.	$[\underbrace{(Ti_{0.18}Fe^{3+}_{0.33}Fe^{2+}_{1.28}Mg_{0.98}Mn_{0.02})^{+0.27}}_{2.79}(Si_{2.78}Al^{iv}_{1.19}Ti_{0.04})^{-1.19}O_{10}(OH)_2]^{-0.92}(K_{0.76}Na_{0.03}Ca_{0.05})^{+0.89}_{0.84}$
"	Oks-4	"	$[\underbrace{(Ti_{0.21}Fe^{3+}_{0.34}Fe^{2+}_{1.32}Mg_{0.98}Mn_{0.02})^{+0.50}}_{2.87}(Si_{2.81}Al^{iv}_{1.19}Ti_{0.01})^{-1.19}O_{10}(OH)_2]^{-0.69}(K_{0.68}Na_{0.05}Ca_{0.04})^{+0.81}_{0.77}$
"	Oks-5	"	$[\underbrace{(Al^{vi}_{0.16}Ti_{0.14}Fe^{3+}_{0.21}Fe^{2+}_{1.51}Mg_{0.70}Mn_{0.05})^{+0.19}}_{2.77}(Si_{2.84}Al^{iv}_{1.17})^{-1.17}O_{10}(OH)_2]^{-0.98}(K_{0.73}Na_{0.11}Ca_{0.03})^{+0.90}_{0.87}$
T	103	"	$[\underbrace{(Ti_{0.04}Fe^{3+}_{1.08}Fe^{2+}_{0.80}Mg_{0.81}Mn_{0.05})^{+0.72}}_{2.78}(Si_{2.43}Al^{iv}_{1.47}Ti_{0.10})^{-1.47}O_{10}(OH)_2]^{-0.75}(K_{0.62}Na_{0.06}Ca_{0.04})^{+0.76}_{0.72}$
"	TAKA 101	H.Y.	$[\underbrace{(Al^{vi}_{0.27}Ti_{0.14}Fe^{3+}_{0.07}Fe^{2+}_{1.26}Mg_{0.91}Mn_{0.02})^{-0.04}}_{2.67}(Si_{2.71}Al^{iv}_{1.29})^{-1.29}O_{10}(OH)_2]^{-1.33}(K_{1.07}Na_{0.18}Ca_{0.04})^{+1.33}_{1.29}$
"	TAKA 102	"	$[\underbrace{(Al^{vi}_{0.23}Ti_{0.14}Fe^{3+}_{0.25}Fe^{2+}_{1.23}Mg_{0.99}Mn_{0.01})^{+0.46}}_{2.85}(Si_{2.71}Al^{iv}_{1.29})^{-1.29}O_{10}(OH)_2]^{-0.83}(K_{0.69}Na_{0.07}Ca_{0.04})^{+0.84}_{0.80}$
"	TK21	(9)	$[\underbrace{(Al^{vi}_{0.13}Ti_{0.17}Fe^{3+}_{0.20}Fe^{2+}_{1.20}Mg_{1.09}Mn_{0.02})^{+0.29}}_{2.81}(Si_{2.74}Al^{iv}_{1.26})^{-1.26}O_{10}(OH)_2]^{-0.97}(K_{0.70}Na_{0.05}Ca_{0.10})^{+0.95}_{0.85}$
"	TK01	"	$[\underbrace{(Al^{vi}_{0.19}Ti_{0.17}Fe^{3+}_{0.24}Fe^{2+}_{1.19}Mg_{1.05}Mn_{0.03})^{+0.51}}_{2.87}(Si_{2.66}Al^{iv}_{1.34})^{-1.34}O_{10}(OH)_2]^{-0.83}(K_{0.75}Na_{0.06}Ca_{0.05})^{+0.91}_{0.86}$
"	TK04	"	$[\underbrace{(Al^{vi}_{0.28}Ti_{0.11}Fe^{3+}_{0.27}Fe^{2+}_{1.32}Mg_{0.59}Mn_{0.06})^{+0.03}}_{2.63}(Si_{2.54}Al^{iv}_{1.46})^{-1.46}O_{10}(OH)_2]^{-1.43}(K_{0.68}Na_{0.07}Ca_{0.06})^{+0.87}_{0.81}$

Rock bodies	Nos.	Ref. or calc.	Structural formulas
T	TK05	(9)	$[\overset{-0.06}{\underbrace{(Al^{vi}_{0.31}Ti_{0.11}Fe^{3+}_{0.25}Fe^{2+}_{1.25}Mg_{0.61}Mn_{0.05})}_{2.58}}\overset{-1.45}{(Si_{2.55}Al^{iv}_{1.45})}O_{10}(OH)_2]^{-1.39}(K_{0.68}Na_{0.04}Ca_{0.04})^{+0.80}_{0.76}$
"	59080201	N.O.	$[\overset{-0.06}{\underbrace{(Al^{vi}_{0.33}Ti_{0.10}Fe^{3+}_{0.79}Fe^{2+}_{0.66}Mg_{0.32}Mn_{0.11})}_{2.31}}\overset{-1.35}{(Si_{2.66}Al^{iv}_{1.35})}O_{10}(OH)_2]^{-1.41}(K_{0.78}Na_{0.08}Ca_{0.03})^{+0.92}_{0.89}$
"	TAKA 105	H.Y.	$[\overset{+0.27}{\underbrace{(Al^{vi}_{0.62}Ti_{0.12}Fe^{3+}_{0.09}Fe^{2+}_{1.27}Mg_{0.51}Mn_{0.05})}_{2.66}}\overset{-1.03}{(Si_{2.98}Al^{iv}_{1.03})}O_{10}(OH)_2]^{-0.76}(K_{0.62}Na_{0.07}Ca_{0.05})^{+0.79}_{0.74}$
"	TAKA 106	"	$[\overset{+0.36}{\underbrace{(Al^{vi}_{0.57}Ti_{0.11}Fe^{3+}_{0.17}Fe^{2+}_{1.43}Mg_{0.38}Mn_{0.04})}_{2.70}}\overset{-1.34}{(Si_{2.66}Al^{iv}_{1.34})}O_{10}(OH)_2]^{-0.98}(K_{0.63}Na_{0.06}Ca_{0.15})^{+0.99}_{0.84}$
"	TAKA 107	"	$[\overset{+0.47}{\underbrace{(Al^{vi}_{0.50}Ti_{0.11}Fe^{3+}_{0.21}Fe^{2+}_{1.38}Mg_{0.52}Mn_{0.05})}_{2.77}}\overset{-1.31}{(Si_{2.69}Al^{iv}_{1.31})}O_{10}(OH)_2]^{-0.84}(K_{0.72}Na_{0.05}Ca_{0.04})^{+0.85}_{0.81}$
"	TK06	M.Y.	$[\overset{+0.38}{\underbrace{(Al^{vi}_{0.36}Ti_{0.12}Fe^{3+}_{0.30}Fe^{2+}_{1.34}Mg_{0.39}Mn_{0.03})}_{2.54}}\overset{-1.42}{(Si_{2.59}Al^{iv}_{1.42})}O_{10}(OH)_2]^{-1.04}(K_{0.69}Na_{0.05}Ca_{0.05})^{+0.84}_{0.79}$
"	TK07	(9)	$[\overset{+0.15}{\underbrace{(Al^{vi}_{0.43}Ti_{0.10}Fe^{3+}_{0.40}Fe^{2+}_{1.20}Mg_{0.37}Mn_{0.06})}_{2.56}}\overset{-1.40}{(Si_{2.60}Al^{iv}_{1.40})}O_{10}(OH)_2]^{-1.25}(K_{0.68}Na_{0.04}Ca_{0.06})^{+0.84}_{0.78}$
"	TK08	J.O.	$[\overset{+0.04}{\underbrace{(Al^{vi}_{0.42}Ti_{0.09}Fe^{3+}_{0.34}Fe^{2+}_{1.23}Mg_{0.41}Mn_{0.06})}_{2.55}}\overset{-1.44}{(Si_{2.57}Al^{iv}_{1.44})}O_{10}(OH)_2]^{-1.40}(K_{0.72}Na_{0.05}Ca_{0.03})^{+0.83}_{0.80}$
"	TK09	(9)	$[\overset{+0.19}{\underbrace{(Al^{vi}_{0.50}Ti_{0.15}Fe^{3+}_{0.27}Fe^{2+}_{1.27}Mg_{0.34}Mn_{0.03})}_{2.56}}\overset{-1.38}{(Si_{2.62}Al^{iv}_{1.38})}O_{10}(OH)_2]^{-1.19}(K_{0.74}Na_{0.04}Ca_{0.06})^{+0.90}_{0.84}$

Rock bodies	Nos.	Ref. or calc.	Structural formulas
T	TK10	J.O.	$[(\underbrace{Al^{vi}_{0.53}Ti_{0.13}Fe^{3+}_{0.40}Fe^{2+}_{1.19}Mg_{0.35}Mn_{0.06}}_{2.66})^{+0.51}(Si_{2.65}Al^{iv}_{1.35})^{-1.35}O_{10}(OH)_2]^{-0.84}(K_{0.77}Na_{0.07}Ca_{0.09})^{+1.02}_{0.93}$
Y	Y 1	(2)	$[(\underbrace{Al^{vi}_{0.28}Ti_{0.20}Fe^{3+}_{0.29}Fe^{2+}_{1.12}Mg_{0.77}Mn_{0.02}}_{2.68})^{+0.32}(Si_{2.86}Al^{iv}_{1.14})^{-1.14}O_{10}(OH)_2]^{-0.82}(K_{0.68}Na_{0.05}Ca_{0.04})^{+0.81}_{0.77}$
"	Y 2	"	$[(\underbrace{Al^{vi}_{0.44}Ti_{0.14}Fe^{3+}_{0.23}Fe^{2+}_{1.16}Mg_{0.79}Mn_{0.04}}_{2.80})^{+0.51}(Si_{2.75}Al^{iv}_{1.25})^{-1.25}O_{10}(OH)_2]^{-0.74}(K_{0.65}Na_{0.02}Ca_{0.03})^{+0.73}_{0.70}$
"	Y 4	"	$[(\underbrace{Al^{vi}_{0.22}Ti_{0.20}Fe^{3+}_{0.34}Fe^{2+}_{1.15}Mg_{0.78}Mn_{0.02}}_{2.71})^{+0.38}(Si_{2.68}Al^{iv}_{1.32})^{-1.32}O_{10}(OH)_2]^{-0.94}(K_{0.82}Na_{0.06}Ca_{0.04})^{+0.96}_{0.92}$
"	Y 5	"	$[(\underbrace{Al^{vi}_{0.21}Ti_{0.20}Fe^{3+}_{0.39}Fe^{2+}_{1.11}Mg_{0.79}Mn_{0.02}}_{2.72})^{+0.46}(Si_{2.69}Al^{iv}_{1.31})^{-1.31}O_{10}(OH)_2]^{-0.85}(K_{0.73}Na_{0.06}Ca_{0.04})^{+0.87}_{0.83}$
"	Y 6	"	$[(\underbrace{Al^{vi}_{0.23}Ti_{0.20}Fe^{3+}_{0.47}Fe^{2+}_{0.97}Mg_{0.79}Mn_{0.03}}_{2.69})^{+0.43}(Si_{2.69}Al^{iv}_{1.31})^{-1.31}O_{10}(OH)_2]^{-0.88}(K_{0.72}Na_{0.08}Ca_{0.03})^{+0.86}_{0.83}$
"	Y 7	"	$[(\underbrace{Al^{vi}_{0.21}Ti_{0.19}Fe^{3+}_{0.49}Fe^{2+}_{0.99}Mg_{0.79}Mn_{0.02}}_{2.69})^{+0.46}(Si_{2.70}Al^{iv}_{1.30})^{-1.30}O_{10}(OH)_2]^{-0.84}(K_{0.75}Na_{0.06}Ca_{0.02})^{+0.85}_{0.83}$
OB	2	N.O.	$[(\underbrace{Al^{vi}_{0.09}Ti_{0.19}Fe^{3+}_{0.54}Fe^{2+}_{1.26}Mg_{0.72}Mn_{0.09}}_{2.89})^{+0.79}(Si_{2.59}Al^{iv}_{1.42})^{-1.42}O_{10}(OH)_2]^{-0.63}(K_{0.73}Na_{0.08}Ca_{0.01})^{+0.83}_{0.82}$
U	Uwajima 1	H.Y.	$[(\underbrace{Al^{vi}_{0.08}Ti_{0.21}Fe^{3+}_{0.02}Fe^{2+}_{1.23}Mg_{1.23}Mn_{0.01}}_{2.78})^{+0.08}(Si_{3.08}Al^{iv}_{0.92})^{-0.92}O_{10}(OH)_2]^{-0.84}(K_{0.61}Na_{0.05}Ca_{0.10})^{+0.86}_{0.76}$

Rock bodies	Nos.	Ref. or calc.	Structural formulas
U	Uwajima 3	H.Y.	$[\underbrace{(Al^{vi}_{0.05}Ti_{0.22}\overset{+0.31}{Fe^{3+}_{0.02}}Fe^{2+}_{1.39}Mg_{1.21}Mn_{0.01})}_{2.90}(Si_{2.82}\overset{-1.18}{Al^{iv}_{1.18}})O_{10}(OH)_2]^{-0.87}(K_{0.80}Na_{0.07}Ca_{0.01})^{+0.89}_{0.88}$
A	Ashizuri 1	"	$[\underbrace{(Al^{vi}_{0.09}Ti_{0.19}\overset{+0.31}{Fe^{3+}_{0.38}}Fe^{2+}_{1.43}Mg_{0.62}Mn_{0.02})}_{2.73}(Si_{2.75}\overset{-1.25}{Al^{iv}_{1.25}})O_{10}(OH)_2]^{-0.94}(K_{0.41}Na_{0.16}Ca_{0.20})^{+0.97}_{0.77}$

Table 4. X-ray Diffraction Powder Data for Chemically Analyzed Biotites

Rock bodies	OS		"		"		S		"		T		"		"	
Nos.	59080302		59080403		59082402		62122604		59102101		103		TK21		TAKA 101	
Analysts	N.O.		"		"		"		"		"		J.O.		H.Y. & T.N.	
	d (Å)	I	d (Å)	I	d (Å)	I	d (Å)	I	d (Å)	I	d (Å)	I	d (Å)	I	d (Å)	I
	10.16	100	10.16	100	10.16	100	10.16	100	10.16	100	10.16	100			10.16	vs
													10.063	100		
							7.132C	4			7.132C	7				
					7.075C	3			7.075C	14			7.075	40		
	5.063	11			5.063	5							5.054	26	5.04	w
			5.035	12			5.035	8	5.007	37	5.035	8				
			4.619	5					4.716	5	4.619	6	4.731	15		
			3.675	5			3.705	4			3.690	3				
	3.545	4			3.531	3	3.559	3	3.531	17	3.559	9	3.542	35		
							3.490C	(3)								
	3.373	100	3.361	100	3.361	100	3.361	100	3.361	100	3.348	100	3.357	63	3.36	vs
	3.241	(4)	3.229	(4)			3.288	(4)								
			3.140	6	3.151	7	3.151	4			3.173	4			3.16	vw
											3.056	3				
	2.938	4	2.938	7			2.957	3	2.928	3'	2.938	3			2.93	vw
											2.704	5				
	2.650	7					2.642	5							2.65	vw
			2.627	6	2.635	3					2.635	29				
	2.520	25	2.513	46	2.513	14	2.513	23	2.513	100	2.513	31	2.518	12	2.52	m
	2.453	5	2.447	4	2.447	5			2.447	4	2.447	15			2.45	vw
											2.268	9			2.28	vw
			2.184	9	2.184	4			2.184	4	2.179	10			2.186	vw
	2.017	15	2.013	27			2.013	10			2.013	21	2.013	10	2.019	m
					2.009	7			2.009	63	2.000	10				
															1.752	vw
	1.677	12	1.677	10	1.677	8	1.679	5	1.677	24	1.677	15	1.677	6	1.681	w
	1.545	7	1.541	10	1.541	7	1.543	4	1.543	9	1.543	17	1.541	3	1.547	w
					1.476	5					1.483	5				
	1.438	5	1.439	8	1.436	6			1.436	17	1.436	6	1.438	4	1.441	w
	1.416	5														
	1.369	7			1.365	5			1.369	5	1.367	8	1.368	6	1.368	w
Polymorphs	2M		2M		2M		mix		2M		2M		?		mix	

Ni-filtered CuKα radiation, 30KV, 15 mA. * No chemical data. C represents chlorite as impurity contained in biotites. mix: Mixture type of 1M·3T and 2M. Number of samples and abbreviations for rock bodies and name of analysts correspond to those in table 1. Abbreviations for intensities are same as those in table 5.

(continued)

Rock bodies	T		"		"		"		"		"		"		"	
Nos.	TAKA 102		59080201		TK08		TK09		TK10		TAKA 105		TAKA 106		TAKA 107	
Analysts	H.Y. & T.N.		N.O.		J.O.		"		"		H.Y. & T.N.		"		"	
	d (Å)	I	d (Å)	I	d (Å)	I	d (Å)	I	d (Å)	I	d (Å)	I	d (Å)	I	d (Å)	I
	10.16	vs	10.16	100							10.16	vs	10.16	vs	10.16	vs
					10.048	100	10.048	100	9.992	100						
	5.04	w			5.039	1	5.039	4			5.04	w	5.04	w	5.04	w
									5.010	2						
	4.62	vw									4.60	vw	4.60	vw	4.60	vw
									3.707	15						
	3.38	vs	3.348	100	3.338	78	3.363	56	3.338	45	3.36	vs	3.36	vs	3.36	vs
	3.16	vw									3.15	vw	3.16	vw	3.16	vw
	2.92	vw									2.92	vw	2.92	vw	2.88	vw
	2.66	vw									2.66	vw	2.66	vw	2.66	vw
			2.627	12					2.629	3						
	2.52	m	2.506	11	2.508	17	2.508	13	2.511	9	2.51	m	2.51	m	2.51	m
	2.45	vw							2.442	2	2.45	vw	2.45	vw	2.45	vw
	2.28	vw											2.28	vw	2.28	vw
	2.181	vw	2.174	7					2.180	2	2.186	vw	2.191	vw	2.181	vw
	2.019	m									2.014	m	2.010	m	2.014	m
					2.006	14	2.006	11	2.012	7						
															1.910	vw
	1.752	vw									1.752	vw	1.752	vw	1.752	vw
	1.681	w	1.671	8	1.675	87	1.672	6	1.675	6	1.678	w	1.675	w	1.678	w
	1.542	w	1.541	8							1.542	w	1.542	w	1.542	w
					1.538	66	1.536	2	1.539	4						
											1.471	vw	1.471	vw	1.471	vw
	1.441	w			1.434	44	1.434	4	1.432	2	1.439	w	1.439	w	1.439	w
	1.368	w	1.365	4	1.364	4	1.361	4	1.363	4	1.368	w	1.365	w	1.366	w
Polymorphs	mix		?		?		?		mix		mix		mix		mix	

(continued)

Rock bodies	U		"		A		Mukaeyama*		Suzuyama*		Kinpōzan*		Kuratayama*	
Nos.	Uwajima 1		Uwajima 3		Ashizuri 1									
Analysts	H.Y. & T.N.		"		"		H.Y. & K.I.		"		"		"	
	d (Å)	I	d (Å)	I	d (Å)	I	d (Å)	I	d (Å)	I	d (Å)	I	d (Å)	I
	10.16	vs	10.16	vs	10.16	vs	10.16	vs	10.16	vs	10.16	vs	10.16	vs
	5.04	w	5.10	w	5.07	w	5.07	w	5.05	w	5.02	w	5.04	w
	4.60	vw	4.60	vw	4.60	vw	4.60	vw					4.60	w
	3.36	vs	3.38	vs	3.36	vs	3.36	vs	3.36	vs	3.36	vs	3.35	vs
	3.15	w	3.18	w	3.16	w	3.16	w	3.16	w	3.15	vw	3.15	w
	2.93	vw			2.94	vw	2.93	w	2.93	w	2.93	vw	2.93	w
			2.80	w										
									2.69	vw				
	2.66	vw	2.66	vw	2.66	vw	2.64	w	2.64	w	2.64	vw	2.64	m
									2.61	vw			2.61	vw
	2.52	m	2.53	m	2.52	m	2.51	m	2.52	m	2.51	m	2.51	m
	2.46	vw	2.46	vw	2.46	vw	2.45	w	2.46	w	2.45	vw	2.45	w
			2.29	vw	2.28	vw								
	2.186	vw	2.186	w	2.191	vw	2.19	w	2.19	w	2.19	vw	2.19	w
	2.021	m	2.023	m	2.019	w	2.01	m	2.01	m	2.01	m	2.01	w
			1.910	vw	1.910	vw								
	1.759	vw	1.752	vw	1.749	vw								
	1.681	w	1.684	w	1.678	w	1.68	w	1.67	w	1.68	w	1.68	w
	1.542	w	1.549	w	1.544	w	1.55	w	1.55	w	1.55	vw	1.55	w
	1.469	vw			1.471	vw								
	1.441	w	1.441	w	1.439	w	1.44	vw	1.44	vw	1.44	w	1.44	vw
	1.370	w	1.372	w	1.368	w	1.36	vw	1.37	w	1.36	vw	1.36	w
Polymorphs	mix		2M		mix		mix		mix		mix		mix	

of 1M polymorph and 3T polymorph were reported by EUGSTER and WONES (1962).

Interplanar spacings and intensities for the analyzed biotites are tabulated in table 4. These data were compared with previous X-ray diffraction powder data and unpublished data summarized by M. ROSS for mica-polymorphs (table 5). These data were also compared with the calculated X-ray powder data by BORG and SMITH (1969). As a result, only 2M polymorph was possible to identify among polymorphs expected in the analyzed biotites by means of X-ray powder diffraction only. Various polymorphs expected in the biotites will be determined with using both the powder diffraction

Table 5. X-ray Diffraction Powder Data for Mica Polymorphs

Minerals	Phlogopite		"		Biotite		Mica		
References	Yoder et al. (1954)		Smith et al. (1956)		Brown (1961)		M. Ross*		
	d (Å)	I	d (Å)	I	d (Å)	I	d (calc)	Fo**	Fo**
	10.13	100			10.1	vs			
			10.05	vs			10.0000	70	46
	5.056	18							
			5.02	w			5.0000	32	35
	4.612	19					4.6000	36	48
			4.59	vw	4.58	w			
			4.55	vw			4.5469	27	31
	4.515	7							
	4.079	5							
			3.93	vvw			3.9212	26	30
	3.814	18							
			3.66	vw			3.6506	56	73
	3.540	33							
			3.39				3.3853	68	76
	3.362	100	3.35	vs	3.36	vs	3.3333	126	118
	3.283	38							
	3.156	9	3.14	w	3.15	vw	3.1357	60	93
	3.040	40							
	2.926	8	2.92	w	2.91	vw	2.9066	83	71
	2.818	22							
			2.71	vw					
	2.651	22	2.64	vw	2.65	s	2.6455	8	69
	2.624	100	2.62	m			2.6151	126	110
	2.522	28	2.51	m	2.51	w	2.5128	30	32
	2.439	40			2.45	s	2.4285	110	93
	2.361	16							
	2.304	9					2.3000	24	35
	2.270	9			2.28	vw	2.2734	27	31
	2.180	45							
	2.039	21							
	2.017	66					2.0266	17	19
	2.000	20			2.002	s	2.0000	51	103
	1.914	5			1.911	vw			
	1.751	3			1.752	vw			
	1.737	5							
	1.677	47			1.672	s			
					1.551	s			
	1.538	50							
	1.521	10			1.527				
Polymorphs	$2M_1$		1M & 3T		1M		1M Mica		

Note. * Unpublished data: calculated X-ray diffraction powder data for differentiating the 1M, $2M_1$, $2M_2$, and 3T polymorphs of mica. ** Calculated structure factors. Abbreviations. -vs: very strong; s: strong; ms: medium strong; m: medium; wm: weak medium; w: weak; vw: very weak; vvw: very very weak.

(continued)

Minerals	Mica			"		"	
References	M. Ross*			"		"	
	d (calc)	Fo**	Fo**	d (calc)	I	d (calc)	I
	10.0000	58	57	10.0000	m	10.0000	ms
	5.0000	69	69	5.0000	s	5.0000	m
	4.6000	36	29			4.6000	ms
	4.5865	69	74	4.5865	ms		
	4.5469	106	113	4.5469	ms	4.5469	vs
	4.4830	42	56				
	4.0532	31	23	4.0532	m		
	3.9212	89	67	3.9212	ms	3.9212	s
	3.7862	92	74				
	3.6506	20	(10)	3.6506	vs	3.6506	s
	3.5165	120	91	3.5164	vs		
	3.3855	116	111			3.3853	s
	3.3333	172	183	3.3333	vs	3.3333	vs
	3.2581	129	117	3.2581	vs		
	3.1357	39	26	3.1357	m	3.1357	s
	3.0184	148	136				
	2.9066	s	118	2.9066	vs	2.9066	s
	2.8002	116	103	2.8002	s		
	2.6992	(12)	11			2.6992	wm
	2.6455	121	117			2.6455	wm,s
	2.6151	s	165			2.6151	vs,w
	2.5128	50	43	2.5128	w,ms	2.5128	w
	2.4285	103	99			2.4285	vs,w
	2.3878	17	-				
	2.3000	25	(8)			2.3000	s
	2.2734	(6)	(2)	2.2734	wm,s	2.2734	wm
	2.1742	51	46				
	2.0326	(2)	(4)				
	2.0266	30	33	2.0266	m	2.0266	w
	2.0000	s	191	2.0000	vs	2.0000	vs
Polymorphs	$2M_1$ Mica			$2M_2$ Mica		3T Mica	

method and the single crystal method in the future.

Chemical Analyses and X-ray Powder Diffraction of Hornblendes

To investigate the element-distribution among coexisting mafic minerals of granitic rocks, separating out of hornblende from coexisting biotite was tried by one of the authors. However, it was too hard in either methods of magnetic separation or heavy liquid separation, and only one hornblende from Shibisan granodiorite could purely be concentrated by 1964, and, since that time, it has been impossible to continue concentration of hornblende on various reasons.

In this paper, chemical analyses in weight percentage of one hornblende from

Shibisan granodiorite and four hornblendes from Ōkueyama granodiorite and their structural formulas calculated on the basis of 24 (O, OH) to the idealized formula, $X_{2-3} Y_5Z_8O_{22}(OH)_2$ in the unit cell are tabulated in table 6. X-ray diffraction powder datum for the hornblende from Shibisan granodiorite is given in table 7. For comparison, previous X-ray diffraction powder datum is placed in the same table.

Table 6. Chemical Analyses of Hornblendes from Granitic Rocks of the Southwestern outer zone-type

Rock bodies	S	OK	"	"	"
Rocks	HBGD	"	"	"	"
Loc or types	Kusubae	Shishigawa	"	"	"
Nos.	62122604	Oks-1	Oks-2	Oks-3	Oks-4
Anal.	N.O.	T.O.	"	"	"
Methods	a	"	"	"	"
Ref.	*	(7)	"	"	"
SiO_2	44.72	44.97	45.98	45.84	47.97
TiO_2	1.40	2.31	1.67	2.02	0.94
Al_2O_3	5.67	6.40	6.65	5.86	4.85
Fe_2O_3	6.18	4.20	3.64	2.85	3.21
FeO	16.62	19.58	18.05	19.22	18.53
MnO	0.75	0.71	0.59	0.74	0.77
MgO	8.04	9.14	9.81	9.15	10.13
CaO	10.79	9.30	9.32	11.37	10.85
Na_2O	1.50	1.28	1.40	1.02	0.91
K_2O	0.80	0.57	0.95	0.47	0.33
H_2O+	2.16	1.96	1.76	1.94	1.88
H2O-	0.67	0.12	0.32	0.06	0.16
P_2O_5	0.23	0.02	0.03	0.02	-
Total	99.53	100.56	100.17	100.56	100.53
Si	6.87	6.830	6.977	6.942	7.214
Al^{iv}	1.03	1.149	1.023	1.046	0.786
Ti	0.10	-	-	-	-
Fe^{3+}	-	0.021	-	0.012	-
Z	8.00	8.000	8.000	8.000	8.000
Al^{vi}	-	-	0.161	-	0.072
Ti	0.06	0.264	1.191	0.227	0.108
Fe^{3+}	0.72	0.462	0.419	0.316	0.361
Fe^{2+}	2.14	2.489	2.286	2.438	2.330
Mn	0.10	0.091	0.073	0.091	0.099
Mg	1.85	2.070	2.213	2.065	2.266
Y	4.87	5.376	5.343	5.137	5.236
Ca	1.78	1.512	1.505	1.820	1.716
Na	0.44	0.374	0.410	0.291	0.262
K	0.14	0.109	0.182	0.091	0.063
X	2.36	1.995	2.097	2.202	2.041
OH	2.20	1.988	1.785	1.965	1.887
P	0.03	†	†	†	†

Number of samples and references and abbreviations correspond to those in table 1. † No description in the original paper.

Table 7. X-ray Diffraction Powder Data for Chemically Analyzed Hornblendes

(1)		(2)	
d (Å)	I	d (Å)	I
8.42	100	8.50	68
4.79	2		
4.55	5	4.57	6
4.23	4	4.23	4
		4.04	4
		3.93	3
3.40	8	3.41	16
3.30	15	3.30	20
3.14	72	3.15	60
2.96	8	2.95	12
2.82	11	2.82	12
		2.76	14
2.72	16	2.72	26
2.61	10	2.60	14
2.55	7	2.56	14
2.39	4	2.39	6
2.35	9	2.35	16
2.29	4	2.29	10
		2.23	4
2.17	6	2.17	14
		2.15	6
2.06	5	2.05	8
2.03	7	2.03	10
		1.989	6
1.875	4	1.909	8
		1.698	3
1.660	6	1.661	10
1.627	4	1.626	6
1.591	3	1.592	10
		1.562	4
		1.523	6
		1.509	6
1.446	4	1.448	16

Ni-filtered CuKα radiation, 30 KV, 15 mA. (1) Hornblende from Shibisan granodiorite (Kusubae-type), No. 62122604. Analyst: N. ŌBA. (2) Hornblende from biotite-gneiss, Jyoganjigawa, Hida. Concentrated by H. SHIBATA. Analyst: H. KODAMA. Unpublished datum.

Chemical Analyses of Granitic Rocks of the Analyzed Biotites

For the purpose to investigate a relation in chemical composition between biotites and its host granitic rocks, the granitic rocks of the Southwestern Outer Zone-type of the analyzed biotites were chemically analyzed. Chemical analyses were determined by a combination method of "standard" and either of "ion exchange resin and chelate titration" or atomic absorption. Chemical analyses in weight percentage with normative minerals are tabulated in table 8. The chemical relationship between the analyzed bitoties and its host granitic rocks will be discussed in another occasion. Besides, chemical analyses of the granitic rocks without chemical data of analyzed biotites are also given in table 9.

Table 8. Chemical Analyses of the Southwestern Outer Zone-Type Granitic Rocks of Analyzed Biotites

Rock bodies	OS	"	"	"	"	"	"	"	"	"	"
Nos.	59080302	2D-17	59080403	5d-5	3-Xe	59082402	8041704	8042710	8031412	8031329	8050245
Anal.	N.O.	"	"	"	"	"	Y.Y.	T.H.	Y.I.	Y.Y.	T.N.
Methods	a	"	"	"	"	"	b	"	"	"	"
Coll.	N.O.	"	"	"	"	"	Y.Y.	T.H.	Y.I.	Y.Y.	T.N.
Ref.	(8)	*	(8)	*	"	(8)	(10)	(3)	(4)	(10)	(6)
SiO_2	67.81	69.06	66.81	66.42	66.67	65.63	66.58	65.86	65.16	68.20	67.18
TiO_2	0.63	0.60	0.65	0.54	0.85	1.14	0.74	0.74	0.72	0.57	0.62
Al_2O_3	14.86	14.15	14.92	15.77	16.38	15.11	16.30	16.18	16.04	15.76	15.80
Fe_2O_3	0.68	0.63	0.87	0.86	1.55	1.50	0.87	0.36	0.51	0.10	0.34
FeO	3.02	3.23	3.26	4.06	3.74	4.40	4.60	4.67	4.44	3.90	4.21
MnO	0.06	0.11	0.10	0.04	0.16	0.10	0.09	0.10	0.10	0.07	0.09
MgO	1.42	1.40	1.79	1.63	1.44	1.74	1.44	1.40	1.39	0.95	1.49
CaO	4.06	3.55	3.82	3.24	3.39	4.25	2.64	2.75	2.90	2.22	2.52
Na_2O	2.65	3.00	2.55	3.30	3.40	2.30	2.69	2.91	2.92	2.84	2.88
K_2O	3.00	3.34	3.00	3.10	1.80	1.85	3.29	3.29	3.38	3.84	3.42
H_2O+	1.44	0.74	1.22	0.51	0.83	1.85	0.62	1.42	2.00	0.98	0.93
H_2O-	0.24	0.04	0.49	0.05	0.36	0.29	0.14	0.10	0.12	0.20	0.22
P_2O_5	0.08	0.02	0.16	0.13	0.02	0.15	0.06	0.06	0.10	0.08	0.10
Total	99.95	99.87	99.64	99.65	100.59	100.31	100.06	99.84	99.78	99.71	99.80
Q	27.3	26.4	27.2	22.3	25.7	32.3	27.7	25.5	24.3	28.2	27.0
Or	18.5	20.0	18.5	19.0	10.0	11.5	19.4	19.4	20.0	22.7	20.0
Ab	24.5	27.5	23.5	30.0	29.5	21.5	22.8	24.6	24.6	24.0	25.2
An	20.0	15.8	18.5	15.5	16.5	21.0	12.7	12.7	13.6	10.5	12.5
C	0.1	-	1.1	1.5	8.1	2.2	3.7	3.2	2.6	3.1	2.9
Wo	-	0.8	-	-	-	-	-	-	-	-	-
En	4.2	4.0	5.2	4.6	3.8	5.2	3.6	3.5	3.4	2.4	3.7
Fs	3.4	3.8	3.8	5.2	3.6	1.0	6.7	7.2	6.7	6.3	6.6
Di	-	-	-	-	-	-	-	-	-	-	-
Hy	-	-	-	-	-	-	-	-	-	-	-
Mt	0.8	0.8	0.9	0.9	1.5	3.3	1.3	0.6	0.7	0.2	0.5
Hm	-	-	-	-	-	-	-	-	-	-	-
Il	1.0	1.0	1.0	0.8	1.2	1.6	1.4	1.4	1.4	1.1	1.2
Ap	0.3	tr.	tr.	0.3	tr.	0.3	0.1	0.1	0.3	0.2	tr.

Abbreviations, notations and number of samples and references correspond to those in table 1. References: (11) ŌBA (1962); (12) OGURA (1970); (13) YAMAMOTO (1975).

(continued)

Rock bodies	OS	S	"	"	"	"	"	"	"	OK	"	"
Nos.	8041106	62122604	23	59102101	2101	2102-2	GD-1	GD-2	GD-3	1	3	6
Anal.	T.N.	N.O.	"	"	"	"	T.A.	"	"	Y.S.	"	A.O.
Methods	b	a	"	"	"	"	"	"	"	"	"	"
Coll.	T.N.	N.O.	"	"	"	"	T.A.	"	"	Y.S.	"	A.O.
Ref.	(6)	(8)	(11)	(8)	(11)	*	(1)	"	"	(5)	"	"
SiO_2	65.04	67.23	68.65	68.00	68.07	66.17	65.42	66.34	66.84	69.42	66.80	65.68
TiO_2	0.71	0.71	0.55	0.67	0.59	0.74	0.65	0.61	0.60	0.42	0.50	0.58
Al_2O_3	16.57	15.28	15.20	14.87	14.98	15.67	15.26	15.21	14.97	13.65	15.03	14.87
Fe_2O_3	0.36	0.90	0.97	0.93	1.18	1.40	1.21	1.16	0.76	0.24	1.17	1.88
FeO	5.05	3.29	2.93	3.19	3.12	3.59	3.54	3.35	3.40	2.32	2.53	2.46
MnO	0.09	0.12	tr.	0.06	0.06	0.09	0.03	0.04	0.04	0.05	0.06	0.12
MgO	1.73	1.23	1.00	1.20	1.58	1.78	1.98	1.74	1.90	0.84	1.31	0.91
CaO	2.92	3.36	2.56	2.87	2.59	3.25	2.50	2.14	2.87	2.34	3.35	3.28
Na_2O	3.09	3.25	3.12	3.15	3.50	3.00	3.20	2.80	3.20	2.98	2.96	3.23
K_2O	2.50	3.55	3.50	3.50	2.90	3.50	3.35	3.76	3.40	3.50	3.50	3.20
H_2O+	1.19	1.07	0.55	1.18	0.75	0.87	1.88	1.74	1.24	2.36	1.34	1.52
H_2O-	0.20	0.26	0.18	0.18	0.32	0.34	0.56	0.58	0.28	1.21	1.00	1.46
P_2O_5	0.05	0.13	0.03	0.18	0.02	0.02	0.03	0.06	0.05	0.06	0.05	0.10
Total	99.50	100.38	99.24	99.98	99.61	100.42	99.61	99.53	99.55	99.39	99.60	99.29
Q	24.9	22.6	27.3	26.3	26.0	22.4	22.7	26.1	23.6	31.0	25.9	25.5
Or	15.0	21.5	21.0	21.0	17.5	21.0	20.5	23.5	20.5	20.7	20.7	18.9
Ab	26.2	30.0	29.0	29.0	32.0	27.5	30.0	26.5	29.5	25.2	25.0	27.3
An	14.5	16.0	13.0	12.5	13.0	16.5	13.0	10.5	13.5	11.2	16.3	15.6
C	3.5	0.3	1.8	1.7	1.6	1.1	2.0	1.0	1.4	0.8	0.4	0.4
Wo	-	-	-	-	-	-	-	-	-	-	-	-
En	4.3	3.6	2.8	3.4	4.4	5.2	5.8	5.2	5.4	-	-	-
Fs	7.9	3.8	3.0	3.6	3.2	3.8	3.7	5.4	4.0	-	-	-
Di	-	-	-	-	-	-	-	-	-	-	-	-
Hy	-	-	-	-	-	-	-	-	-	5.6	6.2	4.5
Mt	0.5	0.9	1.1	0.9	1.4	1.5	1.4	0.6	0.9	0.3	1.7	2.7
Hm	-	-	-	-	-	-	-	-	-	-	-	-
Il	1.4	1.0	0.8	1.0	0.8	1.0	1.0	1.0	1.0	0.8	0.9	1.1
Ap	tr.	0.3	tr.	0.6	tr.	tr.	tr.	0.3	0.3	0.1	0.1	0.2

(continued)

Rock bodies	OK	"	"	"	"	T	"	"	"	"	"	"
Nos.	Oks-1	Oks-2	Oks-3	Oks-4	Oks-5	103	TAKA 101	TAKA 102	TK21	TK01	TK04	TK05
Anal.	T.O.	"	"	"	"	N.O.	"	"	J.O.	M.Y.	"	"
Methods	a	"	"	"	"	"	"	"	"	"	"	"
Coll.	T.O.	"	"	"	"	N.O.	"	"	J.O.	M.Y.	"	"
Ref.	(7)	"	"	"	"	(8)	*	"	(12)	(13)	"	"
SiO_2	61.82	66.10	65.96	70.46	71.46	73.37	72.51	71.98	70.66	71.20	74.80	74.44
TiO_2	0.44	0.33	0.36	0.19	0.29	0.43	0.24	0.26	0.42	0.30	0.18	0.08
Al_2O_3	15.01	14.37	14.85	14.74	13.46	13.64	13.88	13.64	14.84	14.22	14.08	14.25
Fe_2O_3	1.73	1.85	1.77	0.84	0.80	0.50	0.64	1.06	0.24	1.01	0.16	0.66
FeO	4.59	1.99	2.33	0.52	0.85	1.16	1.18	0.75	1.78	1.47	0.65	0.69
MnO	0.13	0.06	0.03	0.06	0.08	tr.	0.10	0.09	tr.	0.07	0.03	0.03
MgO	1.91	1.59	1.59	1.03	0.46	0.71	0.86	0.69	1.00	0.97	0.39	0.31
CaO	3.62	3.16	3.03	2.73	1.13	2.05	2.08	2.15	2.77	2.40	1.34	1.27
Na_2O	4.60	3.30	2.40	3.40	2.20	3.00	3.25	3.15	2.23	2.88	3.54	3.06
K_2O	3.40	3.50	4.00	3.20	5.60	3.90	4.00	4.20	3.20	3.70	4.10	3.72
H_2O+	1.46	1.96	2.10	1.56	1.98	1.29	0.89	1.44	2.16	1.14	0.62	0.66
H_2O-	0.78	1.58	1.38	1.84	1.28	0.32	0.28	0.66	0.86	0.26	0.22	0.34
P_2O_5	0.15	0.06	0.15	0.05	0.06	0.05	0.04	0.05	0.09	0.08	0.02	0.03
Total	99.67	99.85	99.85	99.92	99.63	100.42	99.95	100.12	100.25	99.70	100.13	99.54
Q	9.8	23.4	26.5	30.0	33.3	34.0	30.7	30.8	36.0	32.0	32.8	37.1
Or	20.7	21.7	24.9	19.6	35.0	23.5	24.0	25.5	20.0	22.5	24.5	22.5
Ab	42.4	31.0	22.7	31.5	20.9	27.5	30.0	29.5	21.0	26.5	32.0	28.5
An	10.0	14.7	15.0	13.7	5.4	9.5	9.5	10.0	13.5	11.5	7.0	6.5
C	-	-	1.6	1.0	2.2	1.2	0.9	0.3	3.3	1.5	1.5	3.2
Wo	-	-	-	-	-	-	-	-	-	-	-	-
En	-	-	-	-	-	2.0	2.6	2.0	3.0	2.8	1.2	1.0
Fs	-	-	-	-	-	0.8	1.0	0.2	2.2	1.4	0.6	0.4
Di	5.6	0.8	-	-	-	-	-	-	-	-	-	-
Hy	8.3	5.7	6.7	3.0	1.9	-	-	-	-	-	-	-
Mt	4.1	1.9	1.9	1.0	0.9	0.5	0.8	1.1	0.3	1.1	0.2	0.8
Hm	-	-	-	-	-	-	-	-	-	-	-	-
Il	0.6	0.5	0.5	0.3	0.4	0.6	0.4	0.4	0.6	0.4	0.2	0.2
Ap	0.3	0.1	0.3	0.1	0.2	0.3	0.3	0.3	0.3	0.3	tr.	tr.

(continued)

Rock bodies	T	"	"	"	"	"	"	"	"	Y	"	"
Nos.	59080201	TAKA 105	TAKA 106	TAKA 107	TK06	TK07	TK08	TK09	TK10	Y 1	Y 4	Y 5
Anal.	N.O.	"	"	"	M.Y.	"	J.O.	"	"	T.HA.	"	"
Methods	a	"	"	"	"	"	"	"	"	"	"	"
Coll.	N.O.	"	"	"	M.Y.	"	J.O.	"	"	T.HA.	"	"
Ref.	(8)	*	"	"	"	(13)	(12)	"	"	(2)	"	"
SiO_2	75.67	74.67	75.43	76.03	76.74	76.62	76.37	75.82	76.00	69.54	67.88	69.48
TiO_2	tr.	0.20	0.12	0.15	0.03	0.01	0.11	0.09	0.07	0.25	0.37	0.33
Al_2O_3	13.47	13.15	13.01	12.91	13.30	13.33	13.48	13.94	13.60	14.25	14.49	14.06
Fe_2O_3	0.18	0.63	0.38	0.28	0.06	0.19	0.23	0.19	0.21	1.93	2.52	2.34
FeO	0.54	0.47	0.30	0.35	0.61	0.60	0.66	0.48	0.52	1.12	1.17	0.95
MnO	0.08	tr.	0.06	0.01	0.02	tr.	tr.	tr.	tr.	tr.	0.09	0.01
MgO	0.31	0.39	0.08	0.14	0.23	0.13	0.17	0.25	0.24	1.62	1.22	1.05
CaO	1.47	1.20	0.69	0.58	0.96	0.70	0.82	0.74	1.02	2.76	2.84	2.75
Na_2O	3.15	3.50	3.55	3.50	3.60	3.41	3.10	3.30	3.30	2.60	2.50	2.60
K_2O	3.95	4.20	4.55	4.20	3.86	3.78	4.22	4.10	4.10	3.60	3.40	3.20
H_2O+	0.74	1.12	1.07	0.86	0.48	0.62	0.22	0.32	0.58	1.16	2.56	2.38
H_2O-	0.20	0.48	0.26	0.54	0.28	0.40	0.08	0.24	0.26	0.74	0.70	1.04
P_2O_5	0.03	0.02	0.02	0.02	0.04	0.02	0.01	0.03	0.01	0.25	0.10	0.07
Total	99.79	100.03	99.52	99.57	100.21	99.81	99.47	99.50	99.91	99.82	99.84	100.26
Q	36.0	33.5	34.0	36.2	36.6	36.2	37.7	37.3	36.7	31.8	32.3	34.1
Or	24.0	25.5	27.5	25.5	23.0	23.5	25.5	24.5	24.5	22.0	21.0	20.0
Ab	29.0	32.0	33.0	32.5	32.5	32.5	28.5	30.0	30.0	24.0	23.5	24.5
An	7.5	6.0	3.5	3.0	4.0	4.0	4.5	3.5	5.0	12.0	14.0	13.5
C	1.4	0.8	1.1	1.7	2.0	2.5	2.4	3.2	2.2	1.9	2.1	1.8
Wo	-	-	-	-	-	-	-	-	-	-	-	-
En	1.0	1.2	0.2	0.4	0.6	0.4	0.4	0.6	0.6	4.8	3.6	3.0
Fs	1.0	-	-	0.2	0.8	0.8	0.6	0.4	0.4	-	-	-
Di	-	-	-	-	-	-	-	-	-	-	-	-
Hy	-	-	-	-	-	-	-	-	-	-	-	-
Mt	0.2	0.7	0.5	0.3	0.2	0.2	0.3	0.2	0.3	2.1	2.1	1.8
Hm	-	-	-	-	-	-	-	-	-	-	0.5	0.5
Il	-	0.4	0.2	0.2	tr.	tr.	0.2	0.2	0.2	0.4	0.6	0.4
Ap	tr.	tr.	tr.	tr.	0.3	tr.	tr.	tr.	tr.	0.5	0.3	0.3

(continued)

Rock bodies	Y	"	OB	U	"	A
Nos.	Y 6	Y 7	2	Uwajima 1	Uwajima 3	Ashizuri 1
Anal.	T.HA.	"	K.K.	N.O.	"	"
Methods	a	"	"	"	"	"
Coll.	H.H.	"	K.K.	K.H.	"	H.S.
Ref.	(2)	"	(5)	*	"	"
SiO_2	70.06	69.06	74.62	64.55	66.69	73.41
TiO_2	0.33	0.26	0.19	0.82	0.80	0.39
Al_2O_3	14.27	14.17	13.05	14.82	14.57	12.97
Fe_2O_3	2.50	2.42	0.42	2.03	1.34	1.15
FeO	0.95	0.87	0.98	2.45	2.79	1.09
MnO	0.03	0.05	0.08	0.08	0.06	0.07
MgO	1.01	1.31	0.35	1.96	1.86	0.20
CaO	2.45	2.70	1.01	3.39	3.00	1.20
Na_2O	2.40	2.40	3.14	3.25	2.95	3.50
K_2O	3.20	3.20	3.90	3.40	3.85	4.95
H_2O+	2.20	2.14	0.92	1.85	1.46	0.66
H_2O-	0.92	1.08	0.68	0.76	0.47	0.39
P_2O_5	0.06	0.10	0.03	0.13	0.05	0.05
Total	100.38	99.76	99.37	99.49	99.89	100.03
Q	36.4	35.0	38.2	21.2	23.9	29.8
Or	20.0	20.0	23.0	21.0	23.5	30.0
Ab	22.5	22.5	26.6	30.5	27.0	32.0
An	12.0	13.0	4.8	16.5	14.5	5.0
C	3.1	2.6	1.9	-	0.5	-
Wo	-	-	-	-	-	-
En	3.0	3.8	-	5.6	5.4	0.6
Fs	-	-	-	1.6	2.2	0.6
Di	-	-	-	-	-	-
Hy	-	-	2.2	-	-	-
Mt	1.8	1.8	0.6	2.1	1.5	1.2
Hm	0.6	0.6	-	-	-	-
Il	0.4	0.4	0.4	1.2	1.2	0.6
Ap	0.3	0.3	0.1	0.3	0.3	0.3

Table 9. Chemical Analyses of the Southwestern Outer Zone-Type Granitic Rocks without Chemical Data of Analyzed Biotites

Rock bodies	OS	"	"	"	"	"	"	S	"	"	"
Rocks	HBGD	"	"	"	"	"	"	BX	"	HBGD	"
Loc. or types	Uchinoura	Koyama	"	Tashiro	"	"	Nejime	Kusubae	"	"	"
Nos.	8041205	7122808	7122706	7081411	7082724	8031527	8010809	62122603	606	GD-4	GD-5
Anal.	Y.I.	Y.Y.	Y.I.	T.H.	"	"	T.N.	N.O.	"	T.A.	"
Methods	b	"	"	"	"	"	"	a	"	"	"
Coll.	Y.I.	Y.Y.	Y.I.	T.H.	"	"	T.N.	N.O.	"	T.A.	"
Ref.	(4)	(10)	(4)	(3)	"	"	(6)	*	"	(1)	"
SiO_2	66.58	67.20	66.54	66.68	66.10	65.42	67.82	63.88	60.15	66.22	66.86
TiO_2	0.63	0.62	0.64	0.84	0.77	0.77	0.65	0.96	0.77	0.68	0.53
Al_2O_3	15.78	15.74	16.70	15.68	16.45	16.49	15.34	15.73	16.80	15.05	14.95
Fe_2O_3	0.24	0.13	0.50	0.33	0.23	0.25	0.98	1.50	2.20	0.72	0.58
FeO	4.33	4.20	4.04	4.27	4.44	4.58	4.21	3.20	6.28	3.36	3.63
MnO	0.08	0.09	0.10	0.10	0.08	0.10	0.08	0.12	0.08	0.04	0.04
MgO	1.41	1.11	1.39	1.31	1.42	1.52	1.46	1.63	2.40	2.09	2.01
CaO	2.92	2.45	2.67	2.63	2.76	2.96	2.31	4.00	2.92	2.53	2.62
Na_2O	3.09	2.79	3.01	2.80	3.11	2.88	2.67	3.50	3.70	3.00	3.30
K_2O	3.33	3.48	3.41	3.05	3.28	2.83	3.41	3.70	3.20	3.25	3.67
H_2O+	1.16	1.28	1.27	1.32	1.33	1.13	1.07	1.66	0.83	1.86	1.14
H_2O-	0.24	0.40	0.12	0.28	0.36	0.18	0.14	0.36	0.34	0.44	0.34
P_2O_5	0.09	0.12	0.07	0.09	0.08	0.09	0.05	0.27	0.06	0.06	0.06
Total	99.88	99.61	100.46	99.38	100.41	99.20	100.19	100.51	99.73	99.57	99.73
Q	24.7	28.0	25.7	28.5	24.6	26.2	29.5			24.9	22.1
Or	19.7	20.6	20.0	18.0	19.4	16.7	20.0			20.0	22.0
Ab	26.1	23.6	25.7	23.7	26.3	24.4	22.5			28.0	30.0
An	13.9	11.4	12.5	12.5	13.2	14.1	11.4			12.0	12.5
C	2.0	3.2	3.5	3.2	3.0	3.5	3.1			2.6	1.3
Wo	-	-	-	-	-	-	-			-	-
En	3.5	2.8	3.5	3.3	3.5	3.8	3.6			6.0	5.6
Fs	6.9	6.8	6.1	6.4	6.8	7.1	6.1			4.5	4.8
Di	-	-	-	-	-	-	-			-	-
Hy	-	-	-	-	-	-	-			-	-
Mt	0.4	0.2	0.7	0.5	0.3	0.4	1.4			0.8	0.6
Il	1.2	1.2	1.2	1.6	1.5	1.5	1.2			1.0	0.8
Ap	0.2	0.3	0.3	0.2	0.2	0.2	tr.			0.3	0.3

Note. SK: Shimokoshikijima. ** Cordierite-biotite-bearing dark clot. M.K.: M. KAWAKAMI; T. NA.: T. NAKAYU. References: (14) KAWAKAMI (1972); (15) NAKAYU (1972). Other abbreviations, notations and number of references correspond to those in table 1.

(continued)

Rock bodies	OK	"	"	"	"	T	"	SK	"	"	"	U
Rocks	GP	"	"	"	HBGD	BG	**	HBGD	"	"	"	"
Loc. or types	Ring dike	"	"	"	Shishi-gawa	Grada-tional	Sarugajyō	Teuchi	"	"	"	Fujigao
Nos.	4	5	7	8	Oks-6	TAKA 104	60052002	Te-1	Te-2	Te-3	Te-4	T 1
Anal.	M.M.	"	"	A.O.	T.O.	N.O.	"	M.K.	"	"	"	T.NA.
Methods	a	"	"	"	"	"	"	"	"	"	"	"
Coll.	K.K.	M.M.	K.K.	A.O.	T.O.	N.O.	"	M.K.	"	"	"	T.NA.
Ref.	(5)	"	"	"	(7)	*	"	(14)	"	"	"	(15)
SiO_2	73.02	71.80	71.36	71.78	71.58	75.62	75.64	63.60	66.40	61.42	61.98	67.80
TiO_2	0.12	0.25	0.25	0.25	0.15	0.12	tr.	0.42	0.42	0.58	0.58	0.68
Al_2O_3	13.17	13.85	13.48	13.25	12.48	12.80	14.14	16.66	15.70	16.36	16.80	13.76
Fe_2O_3	0.07	0.32	0.31	0.17	0.51	0.33	0.55	0.91	1.45	1.72	1.29	0.97
FeO	2.41	2.18	2.11	2.39	1.00	0.24	1.87	4.04	2.81	3.83	3.76	2.56
MnO	0.06	0.06	0.07	0.01	0.10	0.04	0.15	0.23	0.04	0.14	0.07	0.04
MgO	0.40	0.59	0.36	0.55	1.16	0.14	0.71	3.00	2.55	3.65	3.92	1.91
CaO	1.21	1.74	1.69	1.30	3.13	0.91	1.05	5.44	4.04	6.25	5.14	3.64
Na_2O	3.72	3.45	3.55	3.01	4.01	3.70	4.10	3.50	2.90	3.10	3.40	2.80
K_2O	5.34	3.85	3.90	4.20	3.70	4.30	0.70	1.60	2.70	1.40	1.60	2.90
H_2O+	0.42	1.04	1.52	1.62	1.22	1.22	1.49	0.94	0.64	1.14	1.08	1.74
H_2O-	0.18	0.60	0.82	1.16	0.52	0.51	0.36	0.10	0.10	0.12	0.06	0.95
P_2O_5	0.05	0.05	0.03	0.02	0.01	0.02	tr.	0.04	0.12	0.03	0.05	0.02
Total	100.17	99.78	99.45	99.80	99.57	99.95	100.76	100.48	99.87	99.74	99.73	99.77
Q	26.1	31.0	30.4	32.6	27.8	33.9		17.7	24.6	17.4	16.5	27.8
Or	31.7	22.8	22.8	25.1	22.5	26.0		9.6	16.2	8.5	9.6	18.0
Ab	31.5	29.2	29.9	25.7	36.9	34.0		31.7	26.6	28.4	31.0	26.0
An	3.3	8.3	8.3	6.4	3.1	4.5		25.3	19.5	27.1	25.5	17.5
C	-	1.0	0.4	1.3	-	0.5		-	1.1	-	0.2	-
Wo	-	-	-	-	-	-		-	-	-	-	0.6
En	-	-	-	-	-	0.4		8.1	7.2	9.4	11.1	5.6
Fs	-	-	-	-	-	0.2		4.5	1.9	2.4	3.4	2.6
Di	2.9	-	-	-	8.3	-		1.3	-	3.7	-	-
Hy	4.0	4.9	4.2	5.2	0.3	-		-	-	-	-	-
Mt	-	0.5	0.5	0.2	0.5	0.3		1.2	2.0	2.5	1.8	1.1
Il	0.3	0.5	0.5	0.5	0.2	0.2		0.6	0.6	0.2	0.8	1.0
Ap	tr.	0.1	tr.	tr.	tr.	tr.		0.2	0.3	tr.	0.2	tr.

(continued)

Rock bodies	U	"	"	"	"	"	"
Rocks	HBGD	"	"	"	"	"	"
Loc. or types	Fujigao	"	Nametoko	"	"	Naru-kawa	"
Nos.	T 2	T 3	T 4	T 5	T 6	T 7	T 8
Anal.	T.NA.	"	"	"	"	"	"
Methods	a	"	"	"	"	"	"
Coll.	T.NA.	"	"	"	"	"	"
Ref.	(15)	"	"	"	"	"	"
SiO_2	67.65	67.77	67.75	65.15	66.57	67.78	67.87
TiO_2	0.52	0.49	0.75	0.90	0.76	0.81	0.76
Al_2O_3	14.49	13.81	14.42	15.23	15.17	13.89	13.53
Fe_2O_3	1.23	0.94	0.65	1.03	0.79	1.41	1.16
FeO	2.61	2.51	2.53	2.66	1.96	2.85	2.56
MnO	0.05	0.08	0.08	0.11	0.09	0.11	0.10
MgO	1.96	2.19	1.74	1.98	2.06	2.22	2.34
CaO	3.05	4.19	3.28	3.33	4.30	3.35	4.19
Na_2O	2.40	2.30	3.00	2.14	2.90	2.30	2.90
K_2O	2.80	2.60	3.36	4.32	2.76	1.90	2.34
H_2O+	2.04	1.94	1.56	1.74	1.78	1.75	1.28
H_2O-	0.72	0.78	0.74	0.95	0.60	1.20	0.53
P_2O_5	0.02	0.03	0.01	0.01	0.02	0.04	0.03
Total	99.54	99.63	99.88	99.55	99.76	99.65	99.65
Q	32.7	30.8	25.4	24.4	25.4	35.6	28.3
Or	17.5	16.0	20.5	26.5	17.0	12.0	14.5
Ab	22.5	21.5	28.0	20.0	27.0	21.5	27.0
An	16.0	20.8	16.5	17.0	20.8	16.5	17.5
C	2.2	-	-	1.3	-	2.8	-
Wo	-	0.2	0.2	-	-	-	1.4
En	5.8	6.2	5.0	5.8	6.0	7.0	6.8
Fs	-	2.4	2.6	2.6	1.6	2.6	2.0
Di	-	-	-	-	-	-	-
Hy	-	-	-	-	-	-	-
Mt	2.7	1.1	0.8	1.2	0.9	1.7	1.4
Il	0.8	1.0	1.0	1.2	1.2	1.2	1.2
Ap	tr.	tr.	tr.	tr.	0.3	0.3	tr.

Summary

Chemical analyses of fifty six biotites from the Southwestern Outer Zone-type granitic rocks and X-ray diffraction powder data of twenty three biotites were summarized in this paper, and structural formulas and polymorphs of the analyzed biotites were examined. As a result, most of the analyzed biotites have the number of additional positive octahedral charge greater than 0.50 in the unit cell or 0.25 in the half-cell in the octahedral layers of the structural formulas, and fall within the bivalent iron-dominant biotite area on the FOSTER's triangular diagram showing the relative quantitative relation between Mg, R^{3+} and Fe^{2+} in octahedral layers. Meanwhile, the analysis of X-ray diffraction powder data shows that only 2M polymorph is identified among polymorphs expected in the analyzed biotites. Besides, chemical analyses of fifty six granitic rocks of the analyzed biotites, those of thirty granitic rocks without chemical analyses of biotites, and those of five hornblendes were also summarized in this paper.

Acknowledgements

The authors are greatly indebted to Dr. H. SHIBATA, Emeritus Professor of Tokyo University of Education, where a part of this study was done in 1963, for much assistance and advice; and to Dr. M.D. FOSTER and Dr. M. ROSS, U.S. Geological Survey, Dr. D.R. WONES, M.I.T., Dr. F.W. DICKSON, Stanford University, and Dr. B. VELDE, University of Sorbonne are acknolwedged for suggestions and discussions of biotite structural formula and polymorph when one of the authors visited in 1967–1968. Dr. M. ROSS allowed one of the authors to use his unpublished data for mica polymorphs. Thanks are also due to Dr. W. SCHREYER, Ruhr University of Bochem, Dr. R. KRETZ, University of Ottawa, Dr. G.W. DEVORE, Florida State University, Dr. A. VOLBORTH, Dr. V.E. SCHEIDE and Dr. D.B. SLEMMONS, University of Nevada, who kindly gave an opportunity to give a lecture concerning this study while one of the authors was staying at each organizations; and to members of the IGCP Project No. 30 Circum-Pacific Plutonism for help and discussions in the course of this work; in particular, to Dr. P. C. BATEMAN, U.S. Geological Survey, for his encouragement. A part of the expense of this study in the initial stage was defrayed by a grant-in-aid for science research from the Japanese Ministry of Education. Finanical supports which made one of the authors possible to continue a series of the research including this study as a visiting researcher at Tokyo University of Education in 1963 and as a researcher on abroad in 1967 were provided by the Japan Society for the Promotion of Science and by the Japanese Ministry of Education.

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APPENDIX

Anbō 安房; Ashizuri 足摺; Fujigao 藤生; Hedaōkawa 辺田大川; Hirabae 平八重; Hiraiwa 平岩; Issō 一湊; Kii 紀伊; Kinpōzan 金峯山; Kosugidani 小杉谷; Kōyama 高山; Kuratayama 蔵多山; Kusubae 楠八重; Manguro 万黒; Miyanoura 宮之浦; Mukaeyama 向江山; Nagata 永田; Nakama 中間; Nametoko 滑床; Narukawa 成川; Nejime 根占; Obira 尾平; Ōkueyama 大崩山; Omine 大峯; Onoaida 尾之間; Ōsumi 大隅; Sarugajyō 猿ヶ城; Sata 佐多; Shibisan 紫尾山; Shimokoshikijima 下甑島; Shinkōji 新光寺; Shishigawa 鹿川; Suzuyama 錫山; Takakumayama 高隈山; Tashiro 田代; Teuchi 手打; Uchinoura 内之浦; Uwajima 宇和島; Yakujima 屋久島; Yakushidani 薬師谷.