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Article

Phengites in garnet–aegirine-augite schists from the Sambagawa metamorphic belt, Bizan district, eastern Shikoku, Japan

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Abstract

The Sambagawa metamorphic belt in the Bizan area consists mainly of pelitic schists, basic schists, and siliceous schists (garnet–aegirine-augite schists), along with minor garnet glaucophane schists. The garnet–aegirine-augite schists consist mainly of quartz and phengite, with minor amounts of amphibole (ferroglaucophane, magnesioriebeckite, riebeckite, Mg-katophorite, winchite, barroisite, ferrobarroisite), garnet, aegirine-augite and albite. Hematite, chlorite, epidote, calcite and titanite occur, occasionally phengites are found in eight modes of occurrence; phengites as inclusions in porphyroblastic garnet (Ph1), amphibole (Ph2), clinopyroxene (Ph3) and albite (Ph4), phengites (Ph5) occurring in the matrix, and phengites as a secondary mineral replacing porphyroblastic garnet (Ph6), amphibole (Ph7) and clinopyroxene (Ph8) along their rim and crack. The diversity of the modes of occurrence and chemical compositions of the phengites reflects two metamorphic events in the garnet–aegirine-augite schists in the Bizan area. Inclusions in garnet (Ph1), amphibole (Ph2) and clinopyroxene (Ph3) and schistosity-forming phengites (Ph5) are representative of the prograde to the peak metamorphism of the eclogitic metamorphic event. Phengites replacing garnet (Ph6), amphibole (Ph7) and clinopyroxene (Ph8) and phengites inclusions in porphyroblastic albites (Ph4) suggest another high-pressure epidote-amphibolite metamorphic event.

Key words: Sambagawa (Sanbagawa) metamorphic belt, Bizan area, garnet, aegirine-augite, phengite

Introduction and petrography of garnet–aegirine-augite schists

The type of metamorphism of the Sambagawa belt is classified as high-pressure intermediate series (Miyashiro, 1973). The dominant rock types within the belt are pelitic, psammitic, siliceous and basic schists. Metamorphic conditions of the belt correspond to the pumpellyite-actinolite, greenschist, blueschist, epidote-amphibolite and eclogite facies. In the Besshi district, the regional metamorphism is divided into four zones based on index minerals in pelitic schists (e.g. Higashino, 1975, 1990; Enami, 1983). These are chlorite (300-360˚C, 5.5-6.5 kbar), garnet (425-470˚C, 7-8.5 kbar), albite-biotite (470-590˚C, 8-9.5 kbar) and oligoclase-biotite (585-635˚C, 9-11 kbar) zones (Enami, 1983; Enami *et al.*, 1994). A number of eclogite-bearing bodies are scattered throughout the albite and the oligoclase biotite zones in the high-grade portions of the metamorphic sequence in the Besshi district.

The main rock types of the Sambagawa metamorphic belt in the Bizan area, eastern Shikoku include pelitic, basic and siliceous schists with minor amounts of psammitic and calcareous schists (Iwasaki, 1963). Basic and pelitic schists show large-scale alternation, and siliceous schists occur as lenses or thin layers within the alterations. There is a tectonic mélange zone containing blocks of serpentinite, metagabbro and garnet-amphibolite (garnet-glaucophane schist in this study) occurs along a ductile shear zone between the spotted and the non-spotted schist zones (Faure, 1983). The garnet glaucophane schists are usually found as lenticular bodies or layers ranging from centimeter to a few meters in thickness in pelitic schists that crop out in the Chikurinji-dani valley (Fig. 1). Iwasaki (1963) reported that the occurrence of phengite (Si 6.83 pfu) in garnet–aegirine-augite-bearing siliceous schists from the Bizan area.

In this paper we describe the modes of occurrence and chemical compositions of phengites in the garnet–aegirine-augite schists in the Bizan area. Petrography of the garnet–aegirine-augite schists have been already reported by Kainuma *et al.* (2012). Three garnet-aegirine-augite schist samples from the Fukumandani Valley in the Bizan area were selected for detailed petrographic examination. Two samples (KB13-1 and KB14-3) were collected from the spotted schist zone, and one sample (KB05) from the non-spotted schist zone. Garnet-aegirine-augite schists (KB13-1, KB14-3) consist mainly of quartz and phengite, with minor amounts of amphibole (ferroglaucophane, magnesioriebeckite, riebeckite, Mg-katophorite, barroisite, ferrobarroisite), garnet, aegirine-augite and albite (Fig. 2). Hematite, chlorite, and epidote occur occasionally. A schistosity is defined by preferred orientation of phengite. Garnet-aegirine-augite schist (KB05) consists mainly of quartz with minor amounts of hematite, epidote and amphibole (magnesioriebeckite, winchite, barroisite). Garnet, calcite, titanite and aegirine-augite occur as accessories. A schistosity is defined by preferred orientation of hematite and quartz.

Phengites in the garnet–aegirine-augite schists from the Bizan

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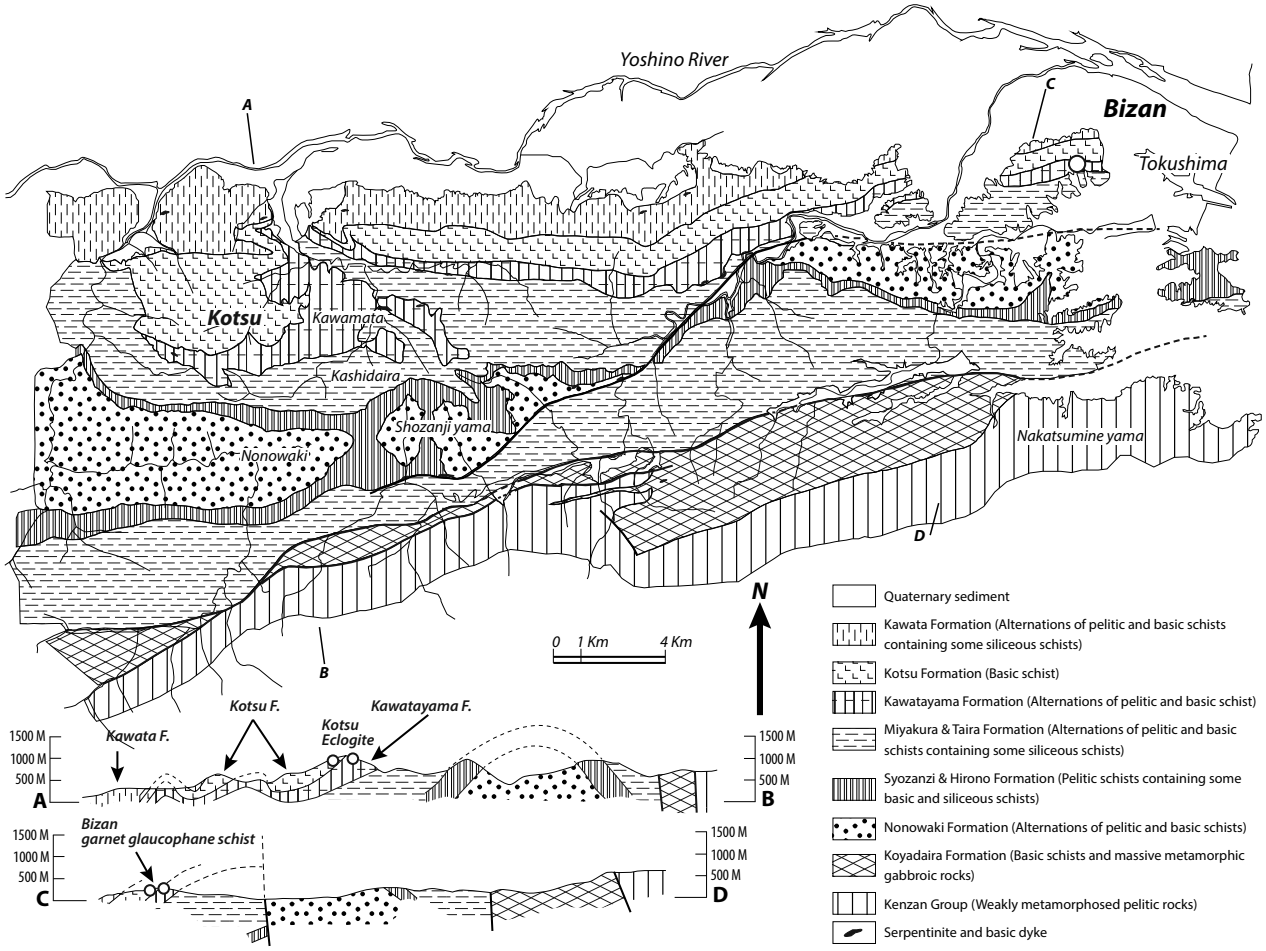

Fig. 1. Geological map of the Kotsu-Bizan area in eastern Shikoku, Sambagawa metamorphic belt (after Kenzan Research Group, 1963). Circle is sample location.

area occur in eight modes of occurrence (Fig. 3). Phengite inclusions in porphyroblastic garnet (Ph1) are subhedral and fine-grained up to 0.05 mm across (Fig. 3a). Phengite (Ph2) inclusions in amphibole are euhedral to subhedral grains up to 0.4 mm across (Fig. 3b). Phengite (Ph3) inclusions in clinopyroxene are larger in grain size among inclusion phengites, which are subhedral grain up to 0.6 mm across (Fig. 3c). Phengite (Ph4) inclusions in albite are subhedral to anhedral grains up to 0.4 mm across (Fig. 3d). Schistosity-forming phengites (Ph5) in the matrix are euhedral to subhedral grains up to 1 mm across (Figs. 2 and 3). Other types of phengites occurring as a secondary mineral replacing porphyroblastic garnet (Ph6), amphibole (Ph7) and clinopyroxene (Ph8) along their rim and crack (Fig. 3e-g). Phengites (Ph6) replacing garnets are subhedral grains up to 0.4 mm across (Fig. 3e). Phengite (Ph7) replacing amphiboles are subhedral to anhedral grains up to 0.6 mm across (Fig. 3f). Phengites (Ph8) replacing clinopyroxenes are subhedral grains are up to 0.5 mm (Fig. 3g). The mineral abbreviations used in the text, tables and figures follow Whitney and Evans (2010) except for Aeg-Aug (aegirine-augite).

Chemical compositions of the phengites

Chemical compositions and zoning of the phengites in garnet–aegirine-augite schists from the Bizan area were examined using electron probe microanalyzers (JEOL JXA-8800M and JXA-8530F) at Shimane University. Analytical conditions applied were 15 kV accelerating voltage, 20 nA specimen current and 5 μm beam diameter. Correction procedure was carried out as described by Bence and Albee (1968). Representative chemical compositions of phengites are listed in Table 1, and shown in Fig. 4. Cr (<0.12 wt%) contents in the phengites are negligible.

Phengites (Ph1) inclusions in garnet in sample KB 13-1 from the Bizan garnet–aegirine-augite schists have Si (6.65-7.19 per formula unit, pfu), X_{Na} (Na / (Na + K)) (0.03-0.06), Fe + Mg (1.42-1.58 pfu) and Ti (0.03-0.08 pfu) (Fig. 4a). Phengite (Ph1) in sample KB 14-3 have slightly lower Si (6.66-6.87 pfu) and higher Fe + Mg (1.49-2.10 pfu). Phengites (Ph2) inclusions in both samples (KB 13-1 and KB 14-3) have similar Si (6.50-7.01 pfu), X_{Na} (0.01-0.05), Fe + Mg (1.21-1.58 pfu) and Ti (0.02-0.07 pfu) compositions (Fig. 4a, b). Some of phengites (Ph2) are zoned, with increasing Si (6.93-6.99 pfu), X_{Na} (0.01-0.02) and Fe + Mg (1.28-1.43 pfu) from core to rim. Phengites (Ph3) occurring in sample

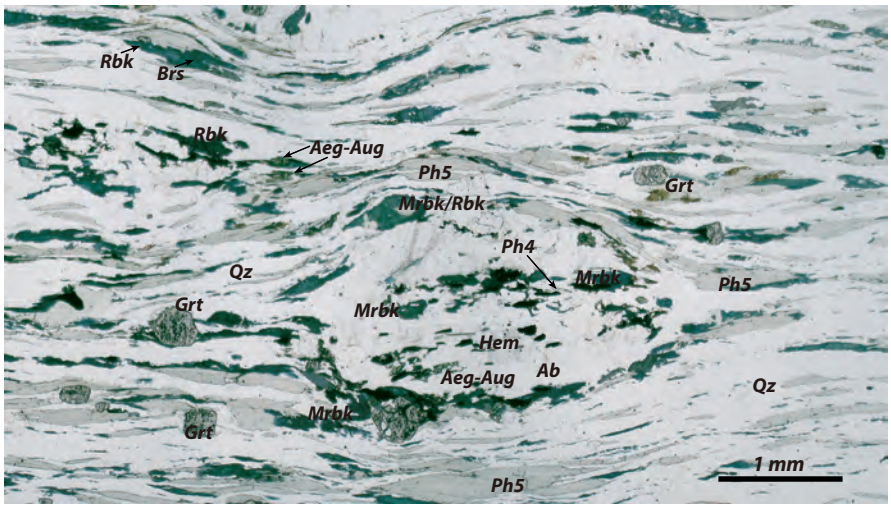

Fig. 2. Photomicrograph of the garnet–aegirine-augite schists from the Bizan area showing porphyroblastic albite, garnet, phengite (Ph5), amphibole (riebeckite and magnesioriebeckite), aegirine-augite and quartz. Porphyroblastic albite contains inclusions of magnesioriebeckite, phengite (Ph4), aegirine-augite and hematite.

KB 13-1 have compositional ranges of Si (6.66-7.08 pfu), Fe+Mg (1.23-1.68 pfu), Ti (0.03-0.08 pfu) and X_{Na} (0.01-0.08). Phengites (Ph4) inclusions in porphyroblastic albite have slightly lower in Si contents (Si 6.57-6.90 pfu, X_{Na} 0.02-0.09, Fe+Mg 1.24-1.62 pfu and Ti 0.01-0.04 pfu) in sample KB 13-1 than the sample KB 14-3 (Si 6.60-7.01 pfu, X_{Na} 0.01-0.10, Fe+Mg 1.15-1.59 pfu and Ti 0.02-0.05 pfu). Some of phengites (Ph4) are zoned, with increasing Si (6.81-6.95 pfu), Fe+Mg (1.17-1.27 pfu) and slightly increasing X_{Na} (0.02-0.03) from core to rim.

Schistosity-forming phengites (Ph5) in sample KB 13-1 and KB 14-3 from the Bizan garnet–aegirine-augite schists have similar in Si (6.53-7.15 pfu), X_{Na} (0.01-0.12), Fe+Mg (1.22-2.17 pfu) and Ti (0.02-0.06 pfu) and lower in sample KB 05 (Si 6.38-6.81 pfu, X_{Na} 0.02-0.09, Fe+Mg 0.56-1.57 pfu and Ti 0-0.03 pfu). Phengites (Ph5) are zoned, with increasing Si (6.58-7.15 pfu) and Fe+Mg (1.34-1.59 pfu) and decreasing X_{Na} (0.12-0.02) from core to rim. Phengites (Ph6) replacing garnets in sample KB 14-3 have compositional ranges of Si (6.75-6.96 pfu), Fe+Mg (1.28-1.66 pfu), Ti (0.02-0.05 pfu) and X_{Na} (0.02-0.10). Phengites (Ph6) replacing garnets are sometimes zoned, with increasing Si (6.76-6.96 pfu) and decreasing Fe+Mg (1.62-1.28 pfu) and X_{Na} (0.07-0.02) from core to rim. Phengites (Ph7) replacing amphiboles in both samples (KB 13-1 and KB 14-3) have similar in Si (6.66-7.05 pfu), X_{Na} (0.01-0.07), Fe+Mg (1.17-1.65 pfu) and Ti (0.02-0.07 pfu). Phengites (Ph7) are zoned, with increasing Si (6.66-7.05 pfu) and decreasing Fe+Mg (1.59-1.26 pfu) and X_{Na} (0.06-0.01) from core to rim.

Phengites (Ph8) replacing clinopyroxenes occur in sample KB 14-3 with Si (6.77-6.92 pfu), Fe+Mg (1.29-1.62 pfu), Ti (0.03-0.06 pfu) and X_{Na} (0.02-0.05), and it shows a similar composition as Ph6 replacing garnets (Fig. 4b). Phengites (Ph8) replacing clinopyroxenes are zoned, with increasing Si (6.76-6.92 pfu), and decreasing Fe+Mg (1.61-1.54 pfu) and X_{Na} (0.04-0.02) from core to rim.

Discussion and Conclusions

There are several modes of occurrence of phengites in the garnet–aegirine-augite schists, and they show a wide range of chemical compositions, i.e. inclusions phengites (Ph1-4: Si 6.50-7.19 pfu, X_{Na} 0-0.10), matrix phengites (Ph5: Si 6.38-7.15 pfu, X_{Na} 0.01-0.12) and phengites replacing matrix minerals (Ph6-8: Si 6.66-7.05 pfu, X_{Na} 0.01-0.10), suggesting a diversity of their equilibrium *P-T* conditions. Iwasaki (1963) reported the occurrence of phengite (Si 6.83 pfu, X_{Na} 0.06) in garnet–aegirine-augite-bearing siliceous schists from the Bizan area. These phengites are ferrimagnesian verity (Fe+Mg 1.68). However, Iwasaki (1963) did not report the mode of occurrence and compositional zoning of phengites. In this study we identified eight modes of occurrence of phengites, and described compositional zoning and possible metamorphic evolution of garnet–aegirine-augite schists from the Bizan area.

Phengite inclusions in garnet (Ph1), amphibole (Ph2) and clinopyroxene (Ph3) have higher in Si contents (6.50-7.19 pfu), and most of the phengite inclusions show compositional zoning with increasing Si contents from the core to the rim, suggesting prograde growth zoning, and it is the product of the prograde to the peak metamorphism (epidote-blueschist and eclogite facies metamorphic conditions). Kabir *et al.* (2014) reported matrix phengites represent prograde to peak metamorphism of the eclogite facies. Phengites (Ph5) in the matrix show a prograde zoning that probably represent a peak metamorphism of the eclogite facies. The estimated peak metamorphic conditions of the eclogites from the Bizan garnet–aegirine-augite schists are 14-16 kbar and 550-570˚C and it is slightly lower than jadeite-beaving garnet

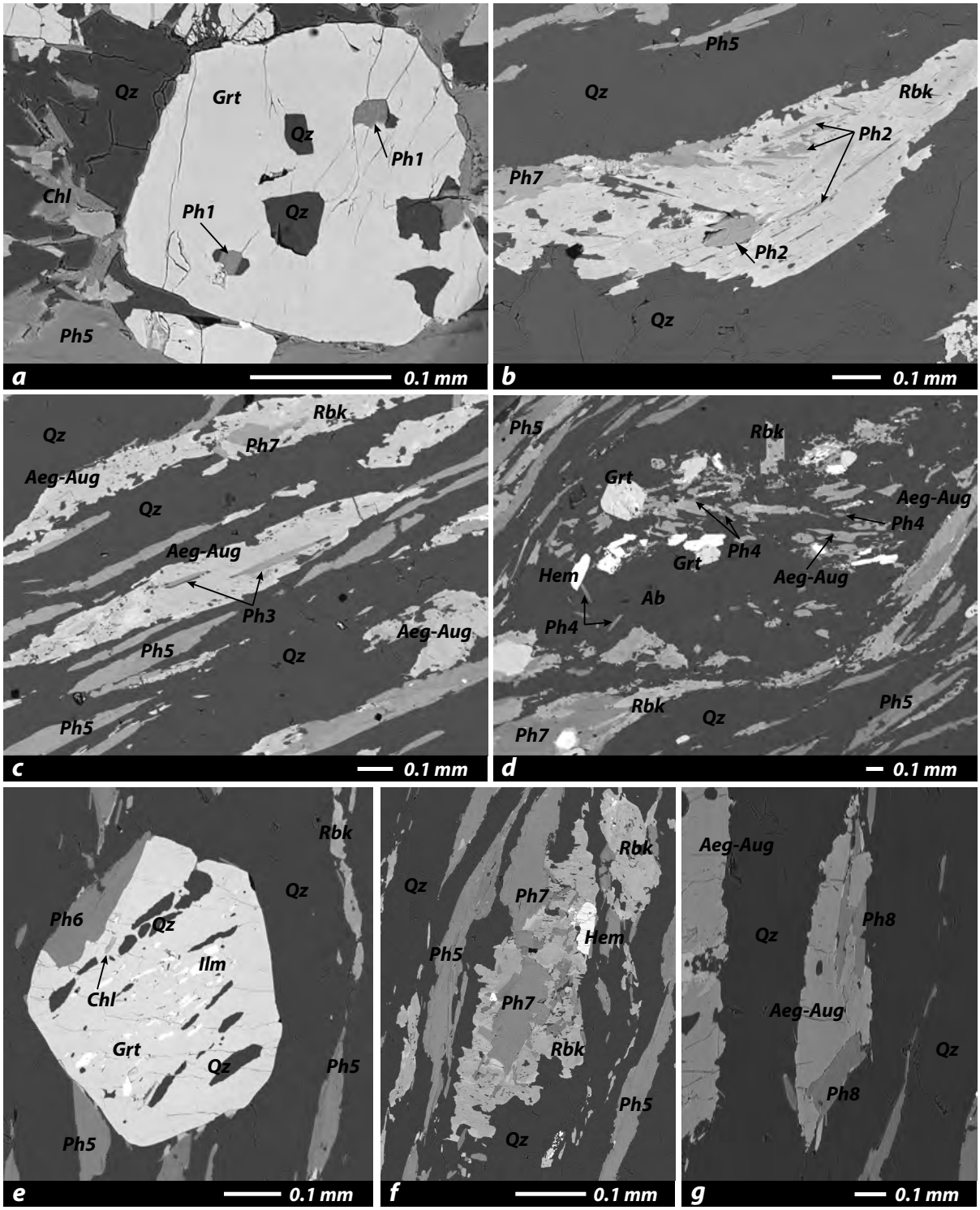

Fig. 3. Backscattered electron images (BEI) of garnet–aegirine-augite schists from the Bizan area showing textural relationships between phengite and the other minerals. (a) Porphyroblastic garnet and the other minerals in the matrix such as phengite (Ph5), chlorite and quartz. Porphyroblastic garnet contains inclusions of phengite (Ph1) and quartz. (b) Amphibole (riebeckite) in the matrix contains inclusions of phengite (Ph2). The amphibole is partly replaced by phengite (Ph7). (c) Clinopyroxene (aegirine-augite) in the matrix contains inclusions of phengite (Ph3). Phengite (Ph5), riebeckitic amphibole and quartz also occur in the matrix. (d) Porphyroblastic albite contains inclusions of phengite (Ph4), garnet, aegirine-augite, riebeckite and hematite. Phengite (Ph5), clinopyroxene (aegirine-augite), riebeckite and quartz occur in the matrix. Riebeckites are partly replaced by phengite (Ph7). (e) Porphyroblastic garnet is replaced by phengite (Ph6). The garnet contains inclusions of chlorite, ilmenite and quartz. Phengite (Ph5), riebeckite and quartz also occur in the matrix. (f) Amphibole (riebeckite) is replaced by phengite (Ph7). (g) Clinopyroxene (aegirine-augite) is replaced by phengite (Ph8).

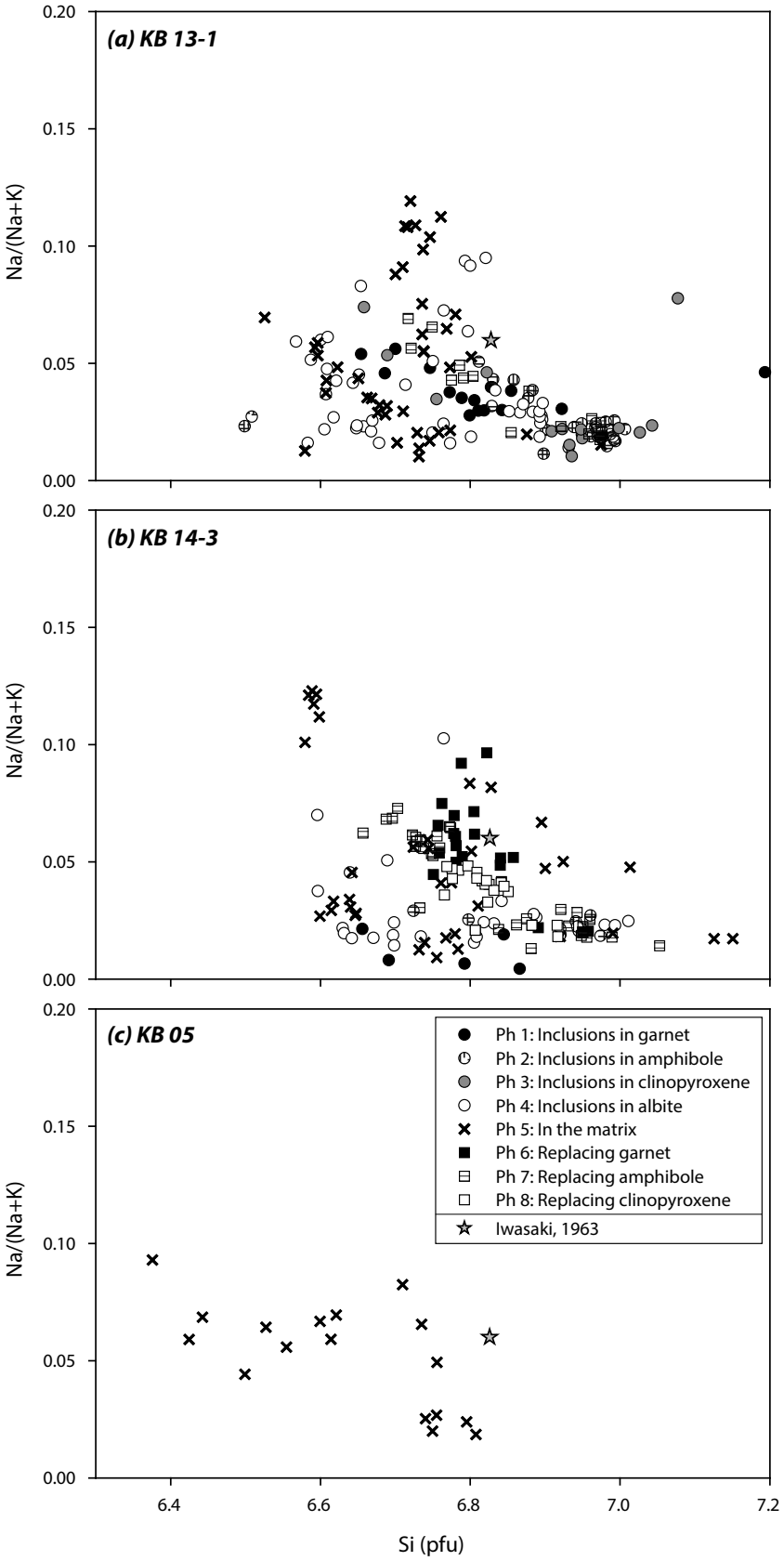

Fig. 4. Chemical compositions of phengites from the garnet–aegirine-augite schists of samples KB 13-1 (a), KB 14-3 (b) and KB 05 (c), star indicates the phengite composition of Iwasaki (1963).

glaucophane schists (580-600˚C and 18-20 kbar) (Kabir and Takasu, 2013; Kabir *et al.*, 2014).

Phengites replacing garnet (Ph6), amphibole (Ph7) and clinopyroxene (Ph8) have wide range in Si (6.66-7.05 pfu) with increasing Si contents from core to rim, indicating another high-pressure metamorphism. This mode of occurrence of phengites probably corresponds to the second high-pressure metamorphic event of epidote-amphibolite facies metamorphism reported by Kabir and Takasu (2013). Kabir and Takasu (2013) reported porphyroblastic albite in the garnet glaucophane schists developed during the second high-pressure metamorphic event. The chemical compositions of phengite inclusions (Ph4: Si 6.57-6.90 pfu, X_{Na} 0.02-0.09, Fe + Mg 1.24-1.62 pfu) in the porphyroblastic albite are similar to those of replacing phengites (Ph6-8: Si 6.66-7.05 pfu, X_{Na} 0.01-0.10, Fe + Mg 1.17-1.66 pfu). These suggest phengite inclusions in porphyroblastic albite also suffered epidote–amphibolite facies metamorphism together with phengites replacing garnet (Ph6), amphibole (Ph7) and clinopyroxene (Ph8).

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（要　旨）

高須　晃・Kabir, Md. Fazle・貝沼雅樹, 2016. 四国東部眉山地域三波川変成帯のざくろ石 - エジリンオージャイト片岩中のフェンジャイト．島根大学地球資源環境学研究報告，34，21-30.

眉山地域の三波川変成帯は泥質片岩，塩基性片岩，珪質片岩（ざくろ石 - エジリンオージャイト片岩）と少量のざくろ石 - 藍閃石片岩からなる．ざくろ石 - エジリンオージャイト片岩の主要構成鉱物は石英とフェンジャイトで，その他に少量の角閃石（鉄藍閃石，マグネシオリーベック閃石，リーベック閃石，マグネシオカタフォル閃石，ウインチ閃石，バロワ閃石，フェロバロワ閃石），ざくろ石，エジリンオージャイトと曹長石からなる．また，赤鉄鉱，緑泥石，緑れん石，方解石，チタン石を含む場合もある．ざくろ石 - エジリンオージャイト片岩のフェンジャイトには以下の 8 種の産状がある．Ph1：斑状変晶ざくろ石中の包有物，Ph2：角閃石中の包有物，Ph3：単斜輝石中の包有物，Ph4：曹長石中の包有物，Ph5：基質中のフェンジャイト，Ph6：斑状変晶ざくろ石を置換，Ph7：角閃石を置換，Ph8：単斜輝石を置換．このような」フェンジャイトの産状と化学組成の多様性は，ざくろ石 - エジリンオージャイト片岩が 2 回の変成イベントを経験するという複雑な変成史に由来する．Ph1～3 および Ph5 はエクロジャイト相変成イベントの昇温期からピーク変成に至るまでの変成作用で形成されたものである．Ph6～8 および Ph4 は 2 回目の変成イベントである緑れん石角閃岩相変成イベントにより形成されたと考えられる．

Table 1. Chemical compositions of phengites from the garnet–aegirine-augite schists.

Sample	KB 13-1																			
Analysis	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Mode	Ph2	Ph2	Ph2	Ph2	Ph2	Ph2	Ph2	Ph2	Ph2	Ph2	Ph2	Ph2	Ph2	Ph2	Ph2	Ph2	Ph2	Ph2	Ph2
							Rim	←	←	←	←	Core	→	→	Rim				
SiO_2	52.61	51.62	52.70	52.48	52.13	52.22	52.52	51.29	51.93	51.84	51.60	51.39	51.59	51.41	50.20	49.24	49.05	49.58	49.33
TiO_2	0.19	0.34	0.34	0.21	0.28	0.37	0.36	0.43	0.34	0.29	0.39	0.35	0.35	0.39	0.43	0.59	0.57	0.57	0.46
Al_2O_3	25.28	24.91	25.19	24.92	24.87	24.70	24.66	23.36	24.62	24.69	24.27	24.57	23.78	23.62	23.62	23.08	23.24	22.98	23.49
FeO*	6.78	7.66	7.24	6.96	7.21	7.30	7.20	8.21	7.24	6.96	7.56	7.47	7.72	7.78	8.59	8.55	8.81	8.57	8.67
MnO	0.08	0.08	0.11	0.11	0.06	0.07	0.11	0.14	0.12	0.08	0.09	0.06	0.11	0.12	0.14	0.08	0.11	0.09	0.09
MgO	2.39	2.22	2.31	2.34	2.37	2.37	2.60	2.44	2.34	2.50	2.38	2.47	2.52	2.49	2.42	2.48	2.63	2.72	2.74
CaO	0.01	0.02	0.02	0.01	0.01	0.01	0.07	0.01	0.00	0.02	0.01	0.02	0.02	0.01	0.02	0.03	0.02	0.03	0.01
Na_2O	0.16	0.14	0.13	0.14	0.16	0.12	0.12	0.11	0.12	0.15	0.12	0.09	0.11	0.10	0.08	0.23	0.27	0.26	0.29
K_2O	9.16	9.34	9.03	9.26	9.23	9.30	9.27	9.54	9.83	9.67	9.86	9.86	9.66	9.97	9.87	9.69	9.85	9.72	9.74
Total	96.66	96.32	97.08	96.43	96.31	96.46	96.89	95.53	96.52	96.19	96.27	96.27	95.84	95.88	95.36	93.96	94.54	94.52	94.83
Cations on the basis of 22 oxygens																			
Si	6.99	6.94	6.99	7.01	6.98	6.99	6.99	6.99	6.97	6.97	6.96	6.93	6.99	6.98	6.90	6.88	6.83	6.88	6.83
Ti	0.02	0.03	0.03	0.02	0.03	0.04	0.04	0.04	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.06	0.06	0.06	0.05
Al	3.96	3.95	3.94	3.92	3.92	3.90	3.87	3.75	3.89	3.91	3.86	3.91	3.80	3.78	3.83	3.80	3.81	3.76	3.84
Fe*	0.75	0.86	0.80	0.78	0.81	0.82	0.80	0.94	0.81	0.78	0.85	0.84	0.87	0.88	0.99	1.00	1.03	1.00	1.00
Mn	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01
Mg	0.47	0.44	0.46	0.47	0.47	0.47	0.52	0.50	0.47	0.50	0.48	0.50	0.51	0.51	0.50	0.52	0.54	0.56	0.57
Ca	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Na	0.04	0.04	0.03	0.04	0.04	0.03	0.03	0.03	0.03	0.04	0.03	0.02	0.03	0.03	0.02	0.06	0.07	0.07	0.08
K	1.55	1.60	1.53	1.58	1.58	1.59	1.58	1.66	1.68	1.66	1.70	1.70	1.67	1.73	1.73	1.73	1.75	1.72	1.72
Total	13.80	13.87	13.79	13.82	13.84	13.84	13.84	13.93	13.91	13.90	13.93	13.94	13.92	13.96	14.02	14.06	14.11	14.07	14.10
X_{Na}	0.03	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.01	0.01	0.04	0.04	0.04	0.04

**Total Fe as FeO*

Sample	KB 13-1																		
Analysis	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	39	40
Mode	Ph2	Ph2	Ph2	Ph2	Ph2	Ph3	Ph3	Ph3	Ph3	Ph3	Ph3	Ph3	Ph3	Ph3	Ph3	Ph3	Ph3	Ph4	Ph4
						Rim	←	←	←	Core	→	Rim							
SiO_2	49.16	50.81	51.24	49.34	49.50	52.08	52.96	51.82	51.78	51.09	51.53	51.81	53.18	52.96	52.54	49.68	52.38	50.82	50.36
TiO_2	0.42	0.50	0.34	0.55	0.57	0.42	0.27	0.36	0.67	0.76	0.73	0.66	0.33	0.40	0.43	0.29	0.76	0.30	0.26
Al_2O_3	23.74	22.93	24.28	23.19	23.46	25.28	24.81	24.99	24.77	24.34	24.12	24.53	25.16	25.04	23.87	22.54	21.39	25.13	25.19
FeO*	8.74	8.41	7.59	8.33	9.00	7.46	7.49	8.00	7.72	7.55	7.41	7.37	7.35	7.06	7.54	9.57	8.29	8.74	8.79
MnO	0.09	0.13	0.07	0.08	0.11	0.09	0.10	0.10	0.13	0.11	0.07	0.10	0.06	0.08	0.09	0.15	0.19	0.09	0.07
MgO	2.59	2.52	2.26	2.80	2.62	2.07	1.99	2.09	2.41	2.60	2.71	2.69	2.57	2.34	2.61	2.41	3.70	1.51	1.49
CaO	0.00	0.01	0.02	0.03	0.03	0.06	0.07	0.06	0.06	0.02	0.04	0.01	0.01	0.02	0.02	0.05	0.57	0.03	0.01
Na_2O	0.34	0.16	0.16	0.29	0.21	0.12	0.14	0.11	0.14	0.13	0.14	0.10	0.12	0.14	0.13	0.07	0.47	0.17	0.18
K_2O	9.74	9.82	9.88	9.67	9.85	9.12	8.95	8.81	9.15	9.24	9.22	9.49	9.74	9.51	9.69	9.49	8.52	9.10	9.21
Total	94.82	95.29	95.85	94.27	95.35	96.70	96.77	96.33	96.83	95.83	95.96	96.75	98.53	97.55	96.90	94.25	96.27	95.89	95.56
Cations on the basis of 22 oxygens																			
Si	6.81	6.98	6.95	6.86	6.83	6.95	7.04	6.95	6.92	6.91	6.95	6.93	6.98	7.00	7.03	6.94	7.08	6.90	6.87
Ti	0.04	0.05	0.03	0.06	0.06	0.04	0.03	0.04	0.07	0.08	0.07	0.07	0.03	0.04	0.04	0.03	0.08	0.03	0.03
Al	3.88	3.71	3.88	3.80	3.82	3.98	3.89	3.95	3.90	3.88	3.83	3.87	3.89	3.90	3.76	3.71	3.41	4.02	4.05
Fe*	1.01	0.97	0.86	0.97	1.04	0.83	0.83	0.90	0.86	0.85	0.84	0.82	0.81	0.78	0.84	1.12	0.94	0.99	1.00
Mn	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.01
Mg	0.54	0.52	0.46	0.58	0.54	0.41	0.40	0.42	0.48	0.52	0.54	0.54	0.50	0.46	0.52	0.50	0.74	0.31	0.30
Ca	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.08	0.00	0.00
Na	0.09	0.04	0.04	0.08	0.06	0.03	0.04	0.03	0.03	0.03	0.04	0.02	0.03	0.04	0.03	0.02	0.12	0.04	0.05
K	1.72	1.72	1.71	1.72	1.73	1.55	1.52	1.51	1.56	1.59	1.59	1.62	1.63	1.60	1.65	1.69	1.47	1.57	1.60
Total	14.11	14.00	13.95	14.08	14.10	13.81	13.76	13.81	13.86	13.89	13.87	13.89	13.88	13.83	13.89	14.03	13.94	13.87	13.91
X_{Na}	0.05	0.02	0.02	0.04	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.08	0.03	0.03

**Total Fe as FeO*

Sample	KB 13-1																		
Analysis	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	1	2	4
Mode	Ph4	Ph4	Ph4	Ph4	Ph4	Ph4	Ph4	Ph4	Ph4	Ph4	Ph4	Ph4	Ph4	Ph4	Ph4	Ph4	Ph1	Ph1	Ph1
								Rim	←	←	←	Core	→	→	→	Rim			
SiO_2	50.29	48.93	49.91	49.92	50.59	50.05	50.45	49.91	49.29	48.60	48.70	49.10	49.17	49.25	49.42	50.73	48.95	48.93	49.83
TiO_2	0.20	0.26	0.23	0.30	0.20	0.22	0.19	0.23	0.41	0.35	0.31	0.29	0.27	0.19	0.24	0.22	0.78	0.65	0.47
Al_2O_3	25.07	24.46	24.56	24.68	25.12	24.86	24.78	24.04	23.74	24.09	23.98	24.62	24.31	24.41	24.24	24.71	23.03	23.26	23.36
FeO*	8.46	8.77	8.92	8.27	8.27	8.60	8.60	8.14	8.42	8.85	8.09	8.17	8.08	7.98	8.24	7.34	9.37	9.41	8.93
MnO	0.11	0.11	0.05	0.07	0.08	0.08	0.09	0.08	0.05	0.08	0.11	0.07	0.08	0.10	0.07	0.05	0.48	0.55	0.47
MgO	1.45	1.45	1.48	1.68	1.65	1.61	1.68	2.39	2.79	2.85	2.81	2.79	2.88	2.80	2.64	2.55	1.99	2.06	2.42
CaO	0.00	0.00	0.00	0.03	0.01	0.02	0.02	0.00	0.02	0.01	0.00	0.00	0.01	0.01	0.00	0.01	0.06	0.05	0.03
Na_2O	0.16	0.18	0.15	0.18	0.17	0.21	0.19	0.12	0.25	0.33	0.42	0.48	0.62	0.61	0.63	0.22	0.21	0.19	0.27
K_2O	9.00	9.11	9.15	9.29	9.35	9.42	9.52	9.53	9.43	9.37	9.29	9.41	9.10	9.19	9.17	9.58	10.27	10.18	10.22
Total	94.73	93.27	94.44	94.42	95.44	95.06	95.52	94.45	94.40	94.53	93.70	94.94	94.51	94.54	94.66	95.41	95.13	95.28	95.98
Cations on the basis of 22 oxygens																			
Si	6.90	6.85	6.89	6.88	6.89	6.87	6.89	6.89	6.83	6.75	6.80	6.76	6.79	6.80	6.82	6.90	6.82	6.81	6.85
Ti	0.02	0.03	0.02	0.03	0.02	0.02	0.02	0.02	0.04	0.04	0.03	0.03	0.03	0.02	0.03	0.02	0.08	0.07	0.05
Al	4.05	4.04	4.00	4.01	4.03	4.02	3.99	3.91	3.88	3.94	3.94	4.00	3.96	3.97	3.94	3.96	3.78	3.82	3.79
Fe*	0.97	1.03	1.03	0.95	0.94	0.99	0.98	0.94	0.98	1.03	0.94	0.94	0.93	0.92	0.95	0.83	1.09	1.09	1.03
Mn	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.06	0.06	0.05
Mg	0.30	0.30	0.30	0.35	0.34	0.33	0.34	0.49	0.58	0.59	0.58	0.57	0.59	0.58	0.54	0.52	0.41	0.43	0.50
Ca	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00
Na	0.04	0.05	0.04	0.05	0.05	0.06	0.05	0.03	0.07	0.09	0.11	0.13	0.17	0.16	0.17	0.06	0.06	0.05	0.07
K	1.57	1.63	1.61	1.63	1.63	1.65	1.66	1.68	1.67	1.66	1.65	1.65	1.60	1.62	1.61	1.66	1.83	1.81	1.79
Total	13.86	13.94	13.91	13.92	13.91	13.95	13.95	13.98	14.05	14.11	14.08	14.10	14.09	14.09	14.07	13.96	14.14	14.14	14.14
X_{Na}	0.03	0.03	0.02	0.03	0.03	0.03	0.03	0.02	0.04	0.05	0.06	0.07	0.09	0.09	0.09	0.03	0.03	0.03	0.04

**Total Fe as FeO*

Table 1. (continued)

Sample	KB 13-1																		
Analysis	5	6	7	8	23	24	25	26	27	28	29	32	33	34	35	36	37	38	39
Mode	Ph1	Ph1	Ph1	Ph1	Ph1	Ph1	Ph1	Ph1	Ph1	Ph1	Ph1	Ph1	Ph5	Ph5	Ph5	Ph5	Ph5	Ph5	Ph5
													Core	→	→	→	→	→	→
SiO_2	50.15	48.48	49.38	48.86	47.80	47.39	47.03	53.53	46.88	47.99	48.54	48.13	49.76	49.63	49.25	49.06	49.25	49.28	48.66
TiO_2	0.40	0.35	0.42	0.41	0.36	0.36	0.35	0.33	0.37	0.41	0.45	0.21	0.19	0.21	0.23	0.24	0.23	0.27	0.37
Al_2O_3	23.06	23.46	23.27	23.35	23.55	23.76	24.22	21.91	23.57	23.01	23.38	24.78	25.72	25.85	25.80	25.73	25.58	25.00	24.24
FeO*	8.64	9.19	9.33	8.94	9.19	9.05	9.31	9.14	9.25	8.89	9.18	6.73	6.91	7.03	7.02	7.57	7.71	8.21	8.85
MnO	0.48	0.58	0.46	0.43	0.55	0.53	0.60	0.57	0.53	0.50	0.52	0.10	0.08	0.07	0.11	0.09	0.04	0.09	0.11
MgO	2.28	2.42	2.42	2.38	2.24	2.27	2.08	1.97	2.24	2.51	2.32	2.76	2.82	2.81	2.71	2.66	2.71	2.72	2.58
CaO	0.06	0.06	0.02	0.02	0.04	0.04	0.04	0.03	0.04	0.04	0.04	0.01	0.08	0.01	0.05	0.07	0.08	0.08	0.04
Na_2O	0.21	0.26	0.28	0.21	0.33	0.39	0.37	0.30	0.32	0.24	0.22	0.72	0.76	0.77	0.82	0.61	0.74	0.68	0.44
K_2O	10.05	10.10	10.19	10.32	9.84	10.00	9.78	9.46	10.00	10.00	9.42	9.47	9.08	9.63	9.24	9.53	9.29	9.40	10.01
Total	95.33	94.89	95.75	94.93	93.88	93.78	93.77	97.24	93.18	93.58	94.06	92.91	95.39	96.00	95.21	95.56	95.63	95.71	95.28
Cations on the basis of 22 oxygens																			
Si	6.92	6.77	6.83	6.81	6.75	6.70	6.66	7.19	6.69	6.79	6.81	6.75	6.76	6.73	6.72	6.70	6.72	6.74	6.74
Ti	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.04	0.04	0.05	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.04
Al	3.75	3.86	3.79	3.84	3.92	3.96	4.04	3.47	3.96	3.84	3.86	4.09	4.12	4.13	4.15	4.14	4.11	4.03	3.95
Fe*	1.00	1.07	1.08	1.04	1.08	1.07	1.10	1.03	1.10	1.05	1.08	0.79	0.78	0.80	0.80	0.86	0.88	0.94	1.02
Mn	0.06	0.07	0.05	0.05	0.07	0.06	0.07	0.07	0.06	0.06	0.06	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Mg	0.47	0.50	0.50	0.50	0.47	0.48	0.44	0.39	0.48	0.53	0.48	0.58	0.57	0.57	0.55	0.54	0.55	0.55	0.53
Ca	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.01
Na	0.06	0.07	0.07	0.06	0.09	0.11	0.10	0.08	0.09	0.07	0.06	0.20	0.20	0.20	0.22	0.16	0.20	0.18	0.12
K	1.77	1.80	1.80	1.84	1.77	1.80	1.77	1.62	1.82	1.80	1.68	1.69	1.57	1.66	1.61	1.66	1.62	1.64	1.77
Total	14.07	14.20	14.17	14.17	14.19	14.23	14.22	13.89	14.25	14.19	14.09	14.13	14.05	14.12	14.09	14.11	14.11	14.13	14.19
X_{Na}	0.03	0.04	0.04	0.03	0.05	0.06	0.05	0.05	0.05	0.04	0.03	0.10	0.11	0.11	0.12	0.09	0.11	0.10	0.06

**Total Fe as FeO*

Sample	KB 13-1																		
Analysis	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58
Mode	Ph5	Ph5	Ph5	Ph5	Ph5	Ph5	Ph5	Ph5	Ph5	Ph5	Ph7	Ph7	Ph7	Ph7	Ph7	Ph7	Ph7	Ph7	Ph7
	→	→	→	→	→	→	→	→	→	Rim									
SiO_2	49.08	48.52	48.57	48.21	49.08	48.91	48.28	48.33	49.07	49.43	52.95	53.02	52.41	52.17	48.47	48.56	48.99	48.83	51.06
TiO_2	0.38	0.23	0.29	0.28	0.35	0.34	0.33	0.36	0.31	0.32	0.28	0.21	0.29	0.51	0.38	0.28	0.31	0.37	0.46
Al_2O_3	24.05	25.08	24.84	24.17	24.03	23.77	24.03	23.99	24.19	23.22	25.24	25.58	25.22	24.44	24.43	24.54	24.42	23.28	23.84
FeO*	8.41	7.74	8.25	8.25	8.73	8.28	8.44	8.67	9.00	8.92	5.66	5.53	5.77	6.08	8.53	8.53	8.33	8.09	7.02
MnO	0.05	0.04	0.09	0.07	0.10	0.07	0.13	0.08	0.12	0.08	0.08	0.10	0.05	0.06	0.08	0.11	0.08	0.10	0.09
MgO	2.79	2.71	2.73	2.81	2.83	2.78	2.82	2.84	2.61	2.44	2.98	2.89	2.85	3.05	2.79	2.93	2.97	2.57	2.66
CaO	0.02	0.01	0.01	0.00	0.01	0.02	0.02	0.05	0.09	0.00	0.03	0.03	0.00	0.05	0.00	0.00	0.00	0.06	0.09
Na_2O	0.49	0.76	0.63	0.52	0.45	0.36	0.38	0.37	0.32	0.13	0.15	0.14	0.14	0.12	0.38	0.47	0.45	0.14	0.17
K_2O	9.81	9.43	9.57	9.77	9.88	9.94	9.95	9.76	9.57	10.14	10.36	10.29	10.35	10.09	9.75	9.54	9.68	10.07	9.71
Total	95.08	94.49	94.98	94.09	95.47	94.47	94.38	94.45	95.28	94.69	97.73	97.78	97.08	96.56	94.81	94.94	95.23	93.52	95.10
Cations on the basis of 22 oxygens																			
Si	6.78	6.71	6.71	6.74	6.77	6.80	6.74	6.74	6.77	6.88	6.98	6.97	6.96	6.97	6.72	6.72	6.75	6.86	6.96
Ti	0.04	0.02	0.03	0.03	0.04	0.04	0.03	0.04	0.03	0.03	0.03	0.02	0.03	0.05	0.04	0.03	0.03	0.04	0.05
Al	3.92	4.09	4.04	3.98	3.91	3.90	3.95	3.94	3.93	3.81	3.92	3.96	3.95	3.85	3.99	4.00	3.97	3.85	3.83
Fe*	0.97	0.90	0.95	0.96	1.01	0.96	0.98	1.01	1.04	1.04	0.62	0.61	0.64	0.68	0.99	0.99	0.96	0.95	0.80
Mn	0.01	0.00	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Mg	0.58	0.56	0.56	0.59	0.58	0.58	0.59	0.59	0.54	0.51	0.59	0.57	0.56	0.61	0.58	0.60	0.61	0.54	0.54
Ca	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.01
Na	0.13	0.20	0.17	0.14	0.12	0.10	0.10	0.10	0.09	0.04	0.04	0.04	0.04	0.03	0.10	0.12	0.12	0.04	0.05
K	1.73	1.66	1.69	1.74	1.74	1.76	1.77	1.73	1.69	1.80	1.74	1.73	1.75	1.72	1.73	1.68	1.70	1.80	1.69
Total	13.64	13.63	13.59	13.62	13.60	13.54	13.65	13.58	13.68	13.75	13.61	13.56	13.57	13.75	13.63	13.57	13.65	13.56	13.57
X_{Na}	0.07	0.11	0.09	0.08	0.06	0.05	0.06	0.05	0.05	0.02	0.02	0.02	0.02	0.02	0.06	0.07	0.07	0.02	0.03

**Total Fe as FeO*

Sample	KB 14-3																		
Analysis	1	2	3	4	5	6	7	8	9	10	11	12	13	14	17	18	20	21	22
Mode	Ph5	Ph5	Ph5	Ph5	Ph5	Ph5	Ph5	Ph5	Ph5	Ph5	Ph6	Ph1	Ph1	Ph2	Ph8	Ph8	Ph8	Ph8	Ph8
	Core	→	→	→	→	→	→	→	→	→	Rim								
SiO_2	49.74	50.62	49.22	48.20	48.49	48.44	48.55	49.21	49.07	50.63	52.28	48.74	46.59	46.79	49.22	48.33	49.90	49.18	49.31
TiO_2	0.16	0.22	0.23	0.31	0.32	0.42	0.48	0.45	0.59	0.56	0.32	0.37	0.58	0.58	0.38	0.32	0.37	0.40	0.41
Al_2O_3	24.75	24.01	24.21	24.46	24.01	23.98	24.21	24.36	23.68	23.40	24.62	21.72	21.26	20.20	23.71	23.55	22.99	23.80	23.73
FeO*	6.57	7.07	7.58	8.24	8.86	8.17	7.94	8.25	8.10	7.84	5.80	10.73	12.56	12.35	8.66	8.98	8.92	8.09	8.93
MnO	0.05	0.08	0.12	0.11	0.11	0.08	0.09	0.06	0.10	0.14	0.08	0.44	0.60	0.57	0.10	0.12	0.08	0.07	0.12
MgO	3.02	3.14	3.04	2.65	2.80	2.59	2.68	2.71	2.68	2.80	2.89	2.64	2.71	2.80	2.68	2.52	2.44	2.71	2.83
CaO	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.02	0.05	0.06	0.04	0.02	0.01	0.07	0.02	0.02
Na_2O	0.57	0.47	0.58	0.39	0.41	0.28	0.28	0.31	0.22	0.13	0.14	0.03	0.05	0.04	0.29	0.32	0.12	0.28	0.33
K_2O	9.71	9.98	9.61	9.85	9.74	9.92	9.96	9.96	10.23	10.23	10.36	9.95	9.90	9.81	9.93	9.83	9.96	9.93	9.85
Total	94.57	95.59	94.59	94.21	94.72	93.87	94.20	95.29	94.67	95.72	96.50	94.66	94.29	93.16	94.98	93.96	94.85	94.47	95.54
Cations on the basis of 22 oxygens																			
Si	6.83	6.90	6.80	6.72	6.74	6.78	6.76	6.77	6.81	6.92	6.99	6.87	6.70	6.80	6.82	6.78	6.92	6.83	6.80
Ti	0.02	0.02	0.02	0.03	0.03	0.04	0.05	0.05	0.06	0.06	0.03	0.04	0.06	0.06	0.04	0.03	0.04	0.04	0.04
Al	4.00	3.85	3.94	4.02	3.94	3.95	3.97	3.95	3.87	3.77	3.88	3.61	3.60	3.46	3.87	3.90	3.76	3.89	3.86
Fe*	0.75	0.81	0.88	0.96	1.03	0.96	0.93	0.95	0.94	0.90	0.65	1.26	1.51	1.50	1.00	1.05	1.03	0.94	1.03
Mn	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.05	0.07	0.07	0.01	0.01	0.01	0.01	0.01
Mg	0.62	0.64	0.63	0.55	0.58	0.54	0.56	0.56	0.56	0.57	0.58	0.55	0.58	0.61	0.55	0.53	0.50	0.56	0.58
Ca	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.01	0.00	0.00
Na	0.15	0.12	0.15	0.10	0.11	0.08	0.08	0.08	0.06	0.03	0.04	0.01	0.01	0.01	0.08	0.09	0.03	0.07	0.09
K	1.70	1.73	1.69	1.75	1.73	1.77	1.77	1.75	1.81	1.78	1.77	1.79	1.81	1.82	1.75	1.76	1.76	1.76	1.73
Total	14.08	13.63	13.59	13.62	13.60	13.54	13.65	13.58	13.68	13.75	13.61	13.56	13.57	13.75	13.63	13.57	13.65	13.56	13.57
X_{Na}	0.08	0.07	0.08	0.06	0.06	0.04	0.04	0.04	0.03	0.02	0.02	0.00	0.01	0.01	0.04	0.05	0.02	0.04	0.05

**Total Fe as FeO*

Table 1. (continued)

Sample	KB 14-3																			
Analysis	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41
Mode	Ph8	Ph8	Ph8	Ph8	Ph8	Ph8	Ph8	Ph8	Ph8	Ph8	Ph8	Ph8	Ph8	Ph8	Ph7	Ph7	Ph7	Ph7	Ph7
				Core	Rim	Core	→	→	→	→	→	→	→	Rim	Rim	←	←	←	←
SiO_2	49.08	49.27	48.98	48.83	50.14	48.49	48.34	48.70	49.21	49.40	48.83	48.97	49.33	49.01	52.12	51.13	51.44	50.95	49.53
TiO_2	0.41	0.42	0.36	0.43	0.46	0.37	0.35	0.32	0.59	0.44	0.35	0.37	0.36	0.43	0.57	0.34	0.41	0.33	0.56
Al_2O_3	23.86	23.79	23.24	24.06	23.39	23.61	23.68	23.40	23.50	23.50	23.40	23.42	23.43	23.49	23.45	24.56	23.98	24.04	24.04
FeO*	8.76	8.42	8.58	8.79	7.90	9.34	9.04	9.12	9.30	8.88	9.03	8.87	9.20	9.49	5.43	6.17	5.99	6.51	6.58
MnO	0.13	0.05	0.06	0.13	0.13	0.13	0.06	0.10	0.09	0.07	0.09	0.08	0.11	0.13	0.08	0.08	0.05	0.12	0.09
MgO	2.89	2.85	2.76	2.58	2.62	2.41	2.55	2.39	2.29	2.37	2.72	2.55	2.45	2.17	3.23	2.76	2.97	2.96	2.71
CaO	0.03	0.00	0.00	0.02	0.01	0.03	0.03	0.03	0.01	0.02	0.01	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.02
Na_2O	0.29	0.31	0.28	0.24	0.16	0.32	0.33	0.27	0.22	0.25	0.29	0.25	0.27	0.29	0.10	0.19	0.12	0.12	0.17
K_2O	9.94	9.90	9.89	9.87	10.01	9.83	9.79	9.83	9.91	9.92	9.80	9.75	9.76	9.86	10.20	9.85	10.06	9.91	9.84
Total	95.39	95.02	94.15	94.96	94.81	94.54	94.16	94.16	95.12	94.84	94.51	94.28	94.91	94.87	95.18	95.08	95.02	94.96	93.54
Cations on the basis of 22 oxygens																			
Si	6.78	6.81	6.84	6.77	6.92	6.78	6.77	6.82	6.82	6.85	6.81	6.83	6.85	6.82	7.05	6.94	6.99	6.95	6.88
Ti	0.04	0.04	0.04	0.05	0.05	0.04	0.04	0.03	0.06	0.05	0.04	0.04	0.04	0.05	0.06	0.03	0.04	0.03	0.06
Al	3.88	3.87	3.83	3.93	3.80	3.89	3.91	3.86	3.84	3.84	3.85	3.85	3.83	3.85	3.74	3.93	3.84	3.86	3.93
Fe*	1.01	0.97	1.00	1.02	0.91	1.09	1.06	1.07	1.08	1.03	1.05	1.03	1.07	1.11	0.61	0.70	0.68	0.74	0.76
Mn	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01
Mg	0.60	0.59	0.57	0.53	0.54	0.50	0.53	0.50	0.47	0.49	0.56	0.53	0.51	0.45	0.65	0.56	0.60	0.60	0.56
Ca	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Na	0.08	0.08	0.08	0.07	0.04	0.09	0.09	0.07	0.06	0.07	0.08	0.07	0.07	0.08	0.03	0.05	0.03	0.03	0.05
K	1.75	1.75	1.76	1.75	1.76	1.75	1.75	1.76	1.75	1.76	1.74	1.74	1.73	1.75	1.76	1.71	1.74	1.72	1.74
Total	14.16	14.12	14.13	14.13	14.04	14.16	14.16	14.13	14.10	14.09	14.14	14.10	14.10	14.12	13.91	13.93	13.94	13.96	13.99
X_{Na}	0.04	0.05	0.04	0.04	0.02	0.05	0.05	0.04	0.03	0.04	0.04	0.04	0.04	0.04	0.01	0.03	0.02	0.02	0.03

**Total Fe as FeO*

Sample	KB 14-3																			
Analysis	42	43	44	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62
Mode	Ph7	Ph7	Ph7	Ph7	Ph7	Ph7	Ph7	Ph7	Ph7	Ph7	Ph7	Ph7	Ph7	Ph7	Ph7	Ph7	Ph7	Ph7	Ph7
	←	←	←	←	←	←	←	←	Core	→	→	→	→	→	→	→	→	→	→
SiO_2	51.53	51.21	48.13	50.72	48.18	48.55	47.97	48.08	46.28	46.97	47.44	46.95	46.95	47.64	47.27	47.56	49.05	49.95	50.26
TiO_2	0.42	0.45	0.33	0.34	0.29	0.39	0.35	0.61	0.36	0.31	0.34	0.38	0.35	0.34	0.34	0.39	0.54	0.36	0.44
Al_2O_3	24.40	24.26	25.01	24.12	24.35	24.45	23.70	24.07	23.78	23.59	24.03	23.56	23.53	23.70	23.54	23.44	23.39	24.93	24.01
FeO*	5.83	5.85	8.06	6.66	7.70	7.89	8.40	8.18	7.97	8.02	7.92	7.90	7.82	8.20	8.43	8.35	7.33	5.77	5.71
MnO	0.11	0.07	0.10	0.07	0.09	0.07	0.15	0.09	0.10	0.10	0.10	0.10	0.12	0.09	0.08	0.11	0.08	0.10	0.10
MgO	2.95	3.00	2.76	2.80	2.72	2.67	2.75	2.68	2.94	2.85	2.82	2.83	2.90	2.89	2.79	2.81	2.69	2.85	3.03
CaO	0.01	0.00	0.02	0.02	0.02	0.07	0.00	0.01	0.04	0.00	0.02	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.00
Na_2O	0.18	0.12	0.44	0.14	0.40	0.41	0.41	0.21	0.42	0.38	0.41	0.41	0.39	0.34	0.37	0.37	0.09	0.15	0.15
K_2O	10.22	10.08	9.07	9.38	8.82	8.94	9.67	9.96	9.70	9.53	9.49	9.59	9.47	9.40	9.47	9.43	9.75	9.87	9.99
Total	95.64	95.05	93.92	94.25	92.57	93.43	93.39	93.88	91.59	91.77	92.56	91.70	91.53	92.61	92.29	92.46	92.93	94.00	93.70
Cations on the basis of 22 oxygens																			
Si	6.96	6.96	6.70	6.95	6.78	6.77	6.76	6.73	6.66	6.73	6.72	6.73	6.73	6.75	6.74	6.76	6.88	6.86	6.93
Ti	0.04	0.05	0.03	0.03	0.03	0.04	0.04	0.06	0.04	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.06	0.04	0.05
Al	3.88	3.88	4.10	3.90	4.04	4.02	3.94	3.97	4.03	3.98	4.01	3.98	3.98	3.96	3.96	3.93	3.87	4.04	3.90
Fe*	0.66	0.66	0.94	0.76	0.91	0.92	0.99	0.96	0.96	0.96	0.94	0.95	0.94	0.97	1.00	0.99	0.86	0.66	0.66
Mn	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Mg	0.59	0.61	0.57	0.57	0.57	0.55	0.58	0.56	0.63	0.61	0.59	0.60	0.62	0.61	0.59	0.59	0.56	0.58	0.62
Ca	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Na	0.05	0.03	0.12	0.04	0.11	0.11	0.11	0.06	0.12	0.10	0.11	0.11	0.11	0.09	0.10	0.10	0.02	0.04	0.04
K	1.76	1.75	1.61	1.64	1.58	1.59	1.74	1.78	1.78	1.74	1.71	1.75	1.73	1.70	1.72	1.71	1.75	1.73	1.76
Total	13.96	13.95	14.08	13.91	14.02	14.03	14.16	14.13	14.24	14.17	14.15	14.18	14.16	14.13	14.16	14.14	14.01	13.97	13.97
X_{Na}	0.03	0.02	0.07	0.02	0.06	0.07	0.06	0.03	0.06	0.06	0.06	0.06	0.06	0.05	0.06	0.06	0.01	0.02	0.02

**Total Fe as FeO*

Sample	KB 14-3																			
Analysis	63	64	65	66	67	68	69	1	2	3	4	5	6	7	8	9	10	11	12
Mode	Ph7	Ph7	Ph7	Ph7	Ph7	Ph7	Ph7	Ph6	Ph6	Ph6	Ph6	Ph6	Ph6	Ph6	Ph6	Ph6	Ph6	Ph6	Ph6
	→	→	Rim											Rim	←	←	←	←	←
SiO_2	49.28	46.52	46.37	50.05	46.98	48.53	47.48	48.50	49.42	49.37	48.80	48.73	48.95	49.37	49.25	49.15	49.19	49.58	49.07
TiO_2	0.63	0.33	0.30	0.57	0.33	0.36	0.41	0.39	0.32	0.39	0.39	0.29	0.35	0.39	0.27	0.22	0.29	0.38	0.39
Al_2O_3	23.03	23.43	23.64	23.31	23.53	23.75	23.54	23.76	23.59	23.52	24.15	23.84	23.77	23.82	24.42	24.16	24.03	23.34	23.95
FeO*	6.68	8.72	7.84	6.33	7.99	7.41	8.11	9.59	8.55	8.47	9.24	8.92	9.58	9.64	9.14	8.87	9.31	9.76	8.75
MnO	0.08	0.11	0.12	0.12	0.11	0.12	0.09	0.19	0.12	0.15	0.21	0.27	0.40	0.29	0.25	0.22	0.19	0.18	0.15
MgO	2.92	2.78	2.70	2.97	2.78	2.65	2.96	2.60	2.92	2.99	2.54	2.72	2.51	2.44	2.45	2.43	2.48	2.48	2.84
CaO	0.00	0.00	0.00	0.02	0.02	0.03	0.04	0.03	0.00	0.00	0.01	0.02	0.03	0.03	0.01	0.01	0.05	0.06	0.01
Na_2O	0.20	0.46	0.49	0.13	0.40	0.14	0.35	0.29	0.34	0.31	0.35	0.40	0.36	0.39	0.57	0.59	0.44	0.32	0.34
K_2O	9.71	9.48	9.48	9.82	9.75	9.59	9.33	9.56	9.40	9.26	9.28	9.26	9.16	9.03	8.58	8.41	8.75	8.88	9.29
Total	92.53	91.82	90.94	93.32	91.89	92.57	92.30	94.90	94.65	94.46	94.96	94.43	95.12	95.40	94.94	94.06	94.73	94.98	94.77
Cations on the basis of 22 oxygens																			
Si	6.92	6.69	6.70	6.95	6.73	6.84	6.75	6.75	6.84	6.84	6.76	6.78	6.78	6.81	6.79	6.82	6.81	6.86	6.79
Ti	0.07	0.04	0.03	0.06	0.04	0.04	0.04	0.04	0.03	0.04	0.04	0.03	0.04	0.04	0.03	0.02	0.03	0.04	0.04
Al	3.81	3.97	4.03	3.82	3.97	3.94	3.94	3.90	3.85	3.84	3.94	3.91	3.88	3.87	3.97	3.95	3.92	3.81	3.91
Fe*	0.78	1.05	0.95	0.74	0.96	0.87	0.96	1.12	0.99	0.98	1.07	1.04	1.11	1.11	1.05	1.03	1.08	1.13	1.01
Mn	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.02	0.03	0.05	0.03	0.03	0.03	0.02	0.02	0.02
Mg	0.61	0.60	0.58	0.62	0.59	0.56	0.63	0.54	0.60	0.62	0.52	0.56	0.52	0.50	0.50	0.50	0.51	0.51	0.59
Ca	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00
Na	0.05	0.13	0.14	0.04	0.11	0.04	0.10	0.08	0.09	0.08	0.09	0.11	0.10	0.10	0.15	0.16	0.12	0.09	0.09
K	1.74	1.74	1.75	1.74	1.78	1.72	1.69	1.70	1.66	1.64	1.64	1.64	1.62	1.59	1.51	1.49	1.54	1.57	1.64
Total	14.00	14.22	14.19	13.97	14.20	14.03	14.13	14.15	14.08	14.06	14.10	14.11	14.10	14.06	14.03	14.00	14.04	14.03	14.08
X_{Na}	0.03	0.07	0.07	0.02	0.06	0.02	0.05	0.04	0.05	0.05	0.05	0.06	0.06	0.06	0.09	0.10	0.07	0.05	0.05

**Total Fe as FeO*

Table 1. (continued)

Sample	KB 14-3																		
Analysis	13	14	15	16	17	18	19	20	21	23	24	25	26	27	28	29	30	31	32
Mode	Ph6	Ph6	Ph6	Ph6	Ph6	Ph6	Ph6	Ph6	Ph6	Ph5	Ph5	Ph5	Ph5	Ph5	Ph5	Ph5	Ph5	Ph5	Ph5
	←	Core	→	→	→	→	→	→	Rim	Rim	←	←	←	←	Core	→	→	→	→
SiO_2	48.59	48.54	48.90	48.85	48.73	49.08	50.10	51.88	51.55	46.47	46.10	47.19	47.68	47.49	47.36	46.92	46.49	48.74	49.73
TiO_2	0.33	0.35	0.35	0.34	0.37	0.41	0.53	0.51	0.37	0.52	0.27	0.27	0.29	0.27	0.31	0.25	0.47	0.39	0.36
Al_2O_3	23.77	23.95	24.09	23.99	23.81	23.28	23.81	24.47	24.53	24.67	25.02	26.27	26.62	26.66	26.48	25.85	24.47	24.65	24.27
FeO*	8.78	8.56	8.81	8.73	9.08	8.65	8.40	7.26	6.67	7.91	8.00	6.91	6.81	6.60	6.82	7.32	8.54	8.45	8.43
MnO	0.16	0.14	0.17	0.25	0.22	0.24	0.19	0.27	0.27	0.09	0.11	0.06	0.09	0.04	0.12	0.06	0.05	0.08	0.10
MgO	2.82	3.00	2.93	2.86	2.62	2.75	2.34	2.56	2.61	2.36	2.65	2.57	2.72	2.65	2.62	2.63	2.45	2.47	2.87
CaO	0.01	0.01	0.02	0.02	0.00	0.00	0.01	0.02	0.02	0.02	0.00	0.02	0.02	0.00	0.01	0.01	0.04	0.02	0.02
Na_2O	0.40	0.43	0.48	0.44	0.32	0.27	0.14	0.13	0.13	0.18	0.69	0.82	0.78	0.83	0.81	0.74	0.29	0.37	0.37
K_2O	9.27	9.28	9.06	8.91	9.38	9.49	9.47	9.65	9.60	9.46	9.26	8.98	8.91	8.99	8.96	8.92	9.15	9.63	9.62
Total	94.14	94.26	94.80	94.38	94.53	94.17	94.98	96.75	95.76	91.69	92.09	93.09	93.92	93.54	93.50	92.70	91.95	94.81	95.77
Cations on the basis of 22 oxygens																			
Si	6.78	6.76	6.76	6.78	6.78	6.84	6.89	6.95	6.96	6.65	6.58	6.59	6.59	6.59	6.58	6.60	6.64	6.74	6.80
Ti	0.03	0.04	0.04	0.03	0.04	0.04	0.05	0.05	0.04	0.06	0.03	0.03	0.03	0.03	0.03	0.03	0.05	0.04	0.04
Al	3.91	3.93	3.93	3.92	3.90	3.83	3.86	3.86	3.90	4.16	4.21	4.33	4.34	4.36	4.34	4.29	4.12	4.02	3.91
Fe*	1.02	1.00	1.02	1.01	1.06	1.01	0.97	0.81	0.75	0.95	0.96	0.81	0.79	0.77	0.79	0.86	1.02	0.98	0.96
Mn	0.02	0.02	0.02	0.03	0.03	0.03	0.02	0.03	0.03	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01
Mg	0.59	0.62	0.60	0.59	0.54	0.57	0.48	0.51	0.52	0.50	0.56	0.54	0.56	0.55	0.54	0.55	0.52	0.51	0.59
Ca	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Na	0.11	0.12	0.13	0.12	0.09	0.07	0.04	0.03	0.03	0.05	0.19	0.22	0.21	0.22	0.22	0.20	0.08	0.10	0.10
K	1.65	1.65	1.60	1.58	1.67	1.69	1.66	1.65	1.65	1.73	1.69	1.60	1.57	1.59	1.59	1.60	1.67	1.70	1.68
Total	14.11	14.12	14.10	14.07	14.10	14.08	13.97	13.91	13.90	14.10	14.23	14.13	14.10	14.11	14.12	14.13	14.12	14.11	14.09
X_{Na}	0.06	0.07	0.07	0.07	0.05	0.04	0.02	0.02	0.02	0.03	0.10	0.12	0.12	0.12	0.12	0.11	0.05	0.06	0.05

**Total Fe as FeO*

Sample	KB 14-3																		
Analysis	33	34	35	36	37	38	39	40	41	42	43	44	45	48	49	50	51	52	53
Mode	Ph5	Ph5	Ph5	Ph5	Ph5	Ph2	Ph2	Ph2	Ph2	Ph2	Ph2	Ph2	Ph2	Ph4	Ph4	Ph4	Ph4	Ph4	Ph4
	→	→	→	→	Rim											Rim	←	←	←
SiO_2	49.97	50.64	51.67	54.60	53.41	50.43	49.37	52.76	51.51	51.61	51.92	51.56	52.78	50.28	53.02	50.16	49.90	49.55	49.40
TiO_2	0.37	0.37	0.34	0.43	0.45	0.41	0.43	0.39	0.62	0.61	0.35	0.68	0.42	0.30	0.23	0.29	0.30	0.33	0.38
Al_2O_3	23.06	23.29	22.55	23.42	22.70	25.46	25.42	25.48	24.58	23.98	24.64	23.62	24.85	24.44	25.12	23.96	24.68	25.25	25.27
FeO*	8.33	8.01	8.41	6.59	7.72	7.12	7.71	5.81	6.59	7.16	6.41	7.16	6.28	6.77	5.99	6.76	6.76	6.30	6.10
MnO	0.10	0.09	0.08	0.09	0.10	0.08	0.11	0.12	0.09	0.11	0.13	0.09	0.12	0.09	0.09	0.10	0.08	0.08	0.09
MgO	3.02	3.09	3.16	3.04	2.86	2.79	2.70	2.93	2.73	2.85	2.88	2.90	2.91	2.28	2.62	2.35	2.27	2.23	2.27
CaO	0.00	0.01	0.03	0.02	0.03	0.00	0.04	0.00	0.01	0.00	0.02	0.02	0.02	0.01	0.01	0.01	0.00	0.00	0.03
Na_2O	0.32	0.34	0.32	0.12	0.11	0.17	0.20	0.17	0.13	0.15	0.14	0.19	0.13	0.14	0.17	0.14	0.17	0.22	0.16
K_2O	9.66	9.68	9.67	10.11	9.86	10.00	10.08	10.36	10.26	10.15	10.36	10.14	10.25	9.93	10.05	9.85	9.74	9.74	9.87
Total	94.83	95.52	96.22	98.42	97.24	96.46	96.05	98.00	96.52	96.63	96.85	96.35	97.74	94.25	97.30	93.61	93.91	93.70	93.56
Cations on the basis of 22 oxygens																			
Si	6.90	6.92	7.02	7.15	7.13	6.80	6.72	6.94	6.92	6.94	6.95	6.96	6.97	6.92	7.01	6.95	6.89	6.84	6.83
Ti	0.04	0.04	0.03	0.04	0.04	0.04	0.04	0.04	0.06	0.06	0.04	0.07	0.04	0.03	0.02	0.03	0.03	0.03	0.04
Al	3.75	3.75	3.61	3.62	3.57	4.04	4.08	3.95	3.89	3.80	3.89	3.76	3.87	3.96	3.92	3.91	4.02	4.11	4.12
Fe*	0.96	0.92	0.95	0.72	0.86	0.80	0.88	0.64	0.74	0.81	0.72	0.81	0.69	0.78	0.66	0.78	0.78	0.73	0.71
Mn	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Mg	0.62	0.63	0.64	0.59	0.57	0.56	0.55	0.57	0.55	0.57	0.57	0.58	0.57	0.47	0.52	0.49	0.47	0.46	0.47
Ca	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Na	0.08	0.09	0.08	0.03	0.03	0.04	0.05	0.04	0.03	0.04	0.04	0.05	0.03	0.04	0.04	0.04	0.05	0.06	0.04
K	1.70	1.69	1.67	1.69	1.68	1.72	1.75	1.74	1.76	1.74	1.77	1.75	1.73	1.74	1.70	1.74	1.71	1.72	1.74
Total	14.08	14.05	14.02	13.86	13.90	14.02	14.09	13.94	13.97	13.98	13.98	13.99	13.93	13.96	13.88	13.95	13.95	13.96	13.96
X_{Na}	0.05	0.05	0.05	0.02	0.02	0.03	0.03	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.03	0.03	0.02

**Total Fe as FeO*

Sample	KB 14-3				KB 05														
Analysis	54	55	56	57	58	59	68	70	72	73	99	101	22	30	28	29	31	32	34
Mode	Ph4	Ph4	Ph4	Ph4	Ph4	Ph4	Ph4	Ph1	Ph6	Ph6	Ph5	Ph5	Ph5	Ph5	Ph5	Ph5	Ph5	Ph5	Ph5
	Core	→	→	Rim															
SiO_2	48.99	47.87	51.31	49.22	53.13	52.91	48.33	49.25	50.83	49.58	49.69	49.66	51.76	49.93	49.15	49.10	50.39	50.88	50.20
TiO_2	0.45	0.28	0.28	0.20	0.17	0.17	2.30	0.30	0.35	0.41	0.14	0.13	0.59	0.15	0.00	0.00	0.07	0.10	0.13
Al_2O_3	25.12	23.56	24.78	23.24	25.79	25.44	23.23	23.55	24.99	24.52	25.14	24.48	29.36	31.99	32.88	33.20	30.75	31.65	31.86
FeO*	6.41	8.12	6.43	8.85	5.98	5.95	10.02	9.37	8.00	9.08	7.86	8.09	4.31	4.39	3.95	4.21	4.45	4.06	4.00
MnO	0.10	0.09	0.10	0.10	0.04	0.09	0.40	0.46	0.18	0.26	0.12	0.07	0.04	0.05	0.04	0.03	0.00	0.02	0.01
MgO	2.26	2.22	2.57	2.33	2.54	2.52	1.91	1.93	1.88	1.79	3.03	3.02	2.01	1.50	1.28	1.26	1.79	1.63	1.42
CaO	0.06	0.07	0.00	0.02	0.00	0.01	0.46	0.06	0.05	0.11	0.02	0.04	0.26	0.00	0.02	0.05	0.04	0.02	0.00
Na_2O	0.12	0.16	0.15	0.18	0.16	0.16	0.14	0.13	0.15	0.14	0.14	0.16	0.39	0.38	0.44	0.35	0.36	0.41	0.35
K_2O	9.78	9.79	9.90	9.82	10.01	10.09	9.44	9.86	9.80	9.98	10.31	10.08	8.44	8.31	8.99	8.50	8.76	8.63	9.03
Total	93.28	92.16	95.51	93.96	97.82	97.33	96.22	94.90	96.23	95.88	96.45	95.73	97.17	96.69	96.75	96.70	96.61	97.38	97.00
Cations on the basis of 22 oxygens																			
Si	6.81	6.82	6.94	6.89	6.98	6.99	6.67	6.85	6.88	6.81	6.75	6.80	6.74	6.53	6.44	6.42	6.61	6.60	6.55
Ti	0.05	0.03	0.03	0.02	0.02	0.02	0.24	0.03	0.04	0.04	0.01	0.01	0.06	0.01	0.00	0.00	0.01	0.01	0.01
Al	4.12	3.95	3.95	3.83	3.99	3.96	3.78	3.86	3.99	3.97	4.03	3.95	4.50	4.93	5.08	5.12	4.76	4.84	4.90
Fe*	0.74	0.97	0.73	1.04	0.66	0.66	1.16	1.09	0.91	1.04	0.89	0.93	0.47	0.48	0.43	0.46	0.49	0.44	0.44
Mn	0.01	0.01	0.01	0.01	0.00	0.01	0.05	0.05	0.02	0.03	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Mg	0.47	0.47	0.52	0.49	0.50	0.50	0.39	0.40	0.38	0.37	0.61	0.62	0.39	0.29	0.25	0.25	0.35	0.31	0.28
Ca	0.01	0.01	0.00	0.00	0.00	0.00	0.07	0.01	0.01	0.02	0.00	0.01	0.04	0.00	0.00	0.01	0.01	0.00	0.00
Na	0.03	0.04	0.04	0.05	0.04	0.04	0.04	0.03	0.04	0.04	0.04	0.04	0.10	0.10	0.11	0.09	0.09	0.10	0.09
K	1.73	1.78	1.71	1.75	1.68	1.70	1.66	1.75	1.69	1.75	1.79	1.76	1.40	1.39	1.50	1.42	1.47	1.43	1.50
Total	13.97	14.09	13.93	14.08	13.87	13.88	14.05	14.08	13.95	14.06	14.13	14.12	13.70	13.73	13.82	13.77	13.78	13.74	13.78
X_{Na}	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.07	0.06	0.07	0.06	0.06	0.07	0.06

**Total Fe as FeO*