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Article

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

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Abstract

The Bizan area is located in Tokushima Prefecture, eastern Shikoku, Japan. The Sambagawa metamorphic belt in the Bizan area consists mainly of pelitic schists, basic schists, and siliceous schists, along with minor garnet glaucophane schists. Siliceous schists containing garnet and aegirine-augite (garnet–aegirine-augite schists) are found in pelitic schists in both spotted and non-spotted schist zones. 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. Amphiboles are found in two modes of occurrence: firstly, as inclusions in albite porphyroblasts (Amp1), and secondly within the matrix (Amp2). Two zoning profiles were identified in the amphiboles: the first exhibits zoning from barroisite cores, through ferroglaucophane mantles, to rims of riebeckite and magnesioriebeckite; and the second from magnesioriebeckite cores, through winchite mantles, to inner rims of magnesioriebeckite, and outermost rims of winchite. A previous study reported only the compositions of magnesioriebeckite rims in strongly zoned amphiboles in the garnet–aegirine-augite schists. The cores and mantles of the zoned amphiboles are ferrobarroisite / barroisite / Mg-katophorite and ferroglaucophane, respectively. We have recognized new types of amphibole zoning, with the core consisting of magnesioriebeckite zoned to a winchite mantle, and passing magnesioriebeckite inner rim to winchite in the outermost rim. This suggests the possibility of fluctuations of *P-T* conditions during metamorphism of garnet–aegirine-augite schists in the Bizan area.

Key words: Sambagawa (Sanbagawa), Bizan, aegirine-augite, magnesioriebeckite, barroisite.

Introduction

The Sambagawa metamorphic belt is a high-*P*/*T* type metamorphic belt that stretches through southwest Japan over a length of approximately 800 km, from Saganoseki Peninsula in Kyushu, to the Kanto Mountains in the northeast (Fig. 1). The dominant rock types within the belt consist of alternations of pelitic and basic schists, along with small amounts of siliceous and psammitic schists. Metamorphic conditions within the belt correspond to the pumpellyite-actinolite, greenschist, blueschist and epidote-amphibolite facies. The metamorphism of the Sambagawa belt in the Besshi district of central Shikoku is divided into chlorite, garnet, albite-biotite and oligoclase-biotite zones, based on the successive appearance of index minerals in pelitic schists (Enami, 1983; Higashino, 1990). Several coarse-grained eclogite-bearing bodies occur within the albite-biotite and oligoclase-biotite zones.

The Bizan area is located in easternmost Shikoku. Like the rest of the Sambagawa belt, the main rock types in the Bizan area include pelitic, basic, and siliceous schists, with minor amounts of psammitic and calcareous schists (Iwasaki, 1963) (Fig. 1). Basic and pelitic schists show large-scale alternation, and siliceous schists occur as lenses or thin layers within these alterations. Faure (1983) suggested that a mélange containing tectonic blocks of serpentinite, metagabbro and garnet-amphibolite (garnet-glaucophane schist) occurs along a ductile shear zone between spotted and non-spotted schist zones.

Iwasaki (1963) reported the occurrence only of magnesiorebeckite in garnet–aegirine-augite-bearing siliceous schists from the Bizan area. In this paper we describe garnet and aegirine-augite-bearing siliceous schists intercalated within pelitic schists in both the spotted and non-spotted schist zones in the Bizan area. We report the petrography of the garnet–aegirine-augite schists, and describe the modes of occurrence and mineral chemistry of amphiboles within the garnet–aegirine-augite schists. The mineral abbreviations used in the text, tables and figures follow Whitney and Evans (2010).

Petrography and modes of occurrence of amphiboles in the Bizan area

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.

KB13-1 and KB14-3:

Garnet–aegirine-augite schists (KB13-1, KB14-3) consist mainly of quartz and phengite, with minor amounts of amphibole (ferroglaucophane, magnesioriebeckite, riebeckite,

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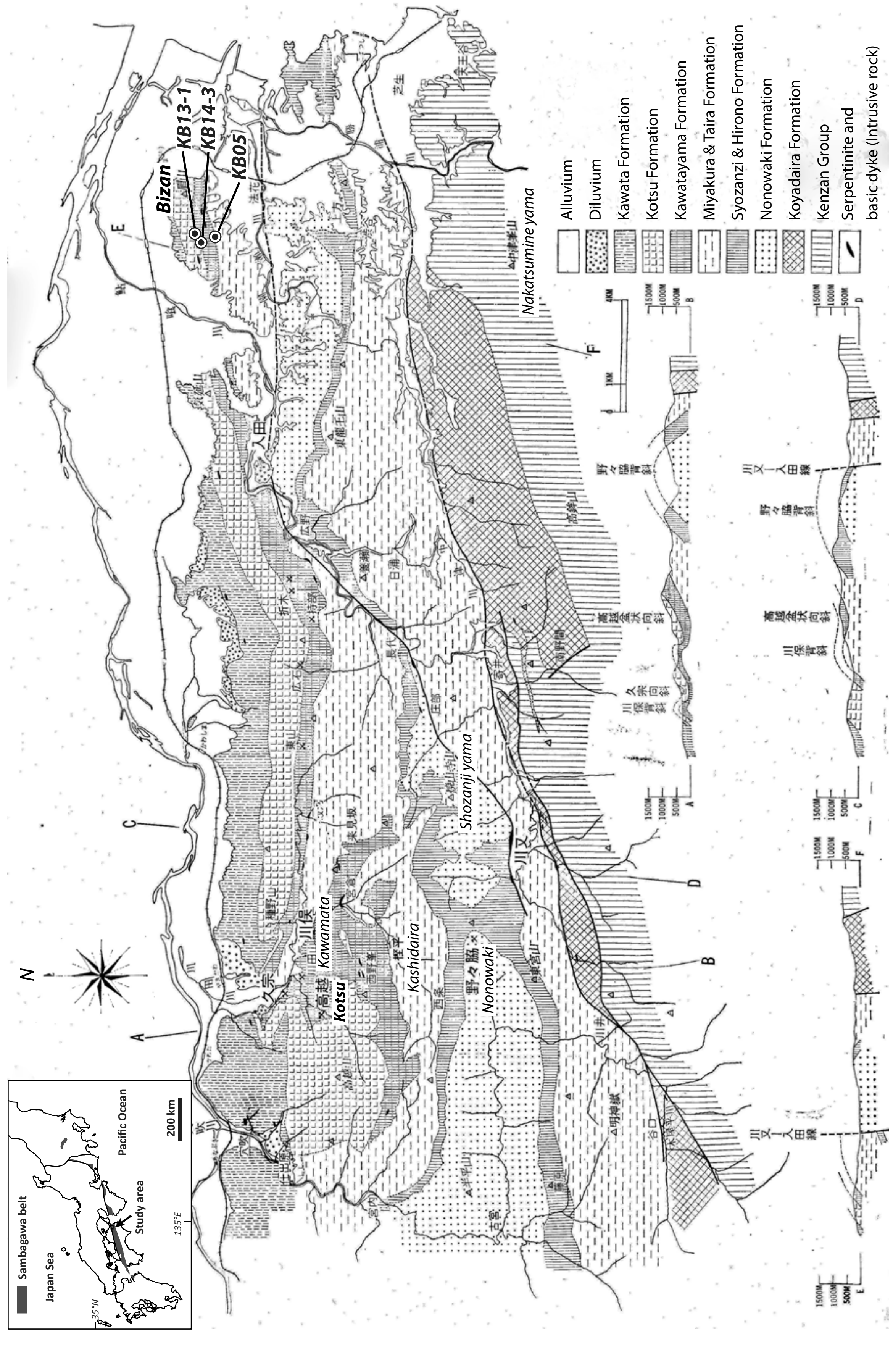

Fig. 1. Geological map of the Sambagawa metamorphic belt in the Kotsu-Bizan district, eastern Shikoku, Japan (after Kenzan Research Group, 1963), and sample localities.

Mg-katophorite, barroisite, ferrobarroisite), garnet, aegirine-augite and albite. Hematite, chlorite, and epidote occur occasionally (Fig. 2a-c). A schistosity is defined by preferred orientation of phengite.

Garnets occur as euhedral to subhedral grains up to 0.6 mm across, some of which are zoned from pale orange cores through to colorless rims. The garnets contain inclusions of phengite, epidote, hematite and quartz. The garnets are occasionally replaced by chlorite and biotite along cracks and at the rims.

Amphiboles have two modes of occurrence. Amphiboles occurring as inclusions in albite porphyroblasts (Amp1) are found as subhedral crystals up to 0.05 mm in length. Amphiboles in the matrix (Amp2) occur as subhedral columnar crystals up to 1.6 mm across, with remarkable optical zoning in which the rims are darker than the cores (X' = light blue-green and Z' = blue-green) (Fig. 2c). These amphiboles contain inclusions of phengite, hematite and quartz.

Two modes of occurrence of aegirine-augite were identified. Aegirine-augites (Aeg-Aug1) occur as inclusions in porphyroblastic albite, in grains up to 0.05 mm across. Aegirine-augites (Aeg-Aug2) in the matrix are found as subhedral to anhedral grains up to 0.7 mm in length, with pleochroism of X' = colorless and Z' = light green (Fig. 2a-b). They contain inclusions of amphibole (Amp1), phengite, hematite and quartz, and are partially replaced by chlorite along their cleavages.

Phengites have four modes of occurrences. Phengites occurring as inclusions within garnet (Ph1), amphibole (Ph2) and aegirine-augite (Ph3) are 0.2 mm across. Phengites within the matrix (Ph4) occur as euhedral to subhedral grains up to 2 mm in width. Epidotes have two modes of occurrence. Epidotes found as inclusions in garnet (Ep1) are fine-grained, reaching only 0.05 mm in diameter. Epidotes (Ep2) in the matrix occur as subhedral to anhedral crystals about 0.1 mm in size. Porphyroblastic albite crystals up to 2 mm across contain inclusions of garnet, amphibole (Amp1), aegirine-augite (Aeg-Aug1), phengite and quartz. Chlorites and hematites in the matrix reach 0.6 mm in size. Quartz in the matrix occurs as anhedral granular crystals up to 0.7 mm across.

KB05:

Garnet–aegirine-augite schist (KB05) from Fukumandani valley consists mainly of quartz, with minor amounts of hematite, epidote and amphibole (magnesioriebeckite, winchite, barroisite) (Fig. 2d-f). Garnet, calcite, titanite and aegirine-augite occur as accessories. A schistosity is defined by preferred orientation of hematite and quartz.

Garnets have three modes of occurrence in this sample. Garnet inclusions in both amphibole (Grt1) and epidote (Grt2) occur as tiny euhedral grains up to 0.02 mm in diameter. Garnets (Grt3) within the matrix are found as granular euhedral crystals up to 0.03 mm in diameter.

Amphiboles (Amp2) occur in the matrix as subhedral prismatic grains up to 0.5 mm long. They are optically zoned, with rims darker than the cores (X' = light blue-green and Z' = blue-green). They also contain inclusions of fine-grained garnet (Grt1) and hematite.

Aegirine-augites in the matrix form anhedral columnar crystals up to 0.5 mm in length. Epidotes occur as subhedral grains in the matrix, and contain garnet, hematite and quartz inclusions. Hematites in the matrix reach 0.3 mm across in width, while anhedral granular calcite reaches only 0.05 mm across. Quartz is also found in the matrix, as granular crystals up to 0.05 mm in diameter.

Chemical compositions of the amphiboles

Chemical compositions and zoning of the amphiboles in the garnet–aegirine-augite schists from the Bizan area were examined at Shimane University using two electron probe microanalyzers (JEOL JXA-8800M and JXA-8530F). Analytical conditions used 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). Fe^{3+} estimation for amphiboles used the 13eCNK method by Leake *et al*. (1997). The chemical compositions of amphiboles in all modes of occurrence are listed in Table 1, and illustrated in Fig. 3-6.

Amphiboles (Amp1) occurring in sample KB13-1 as inclusions in porphyroblastic albite are compositionally zoned, with ferro-barroisite and barroisite cores with Si = 7.09-7.39 pfu, Na_B = 1.29-1.49 pfu and X_{Mg} = 0.43-0.66, and riebeckite rims with Si = 7.59-7.87 pfu, Na_B = 1.75-1.94 pfu and X_{Mg} = 0.29-0.38 (Fig. 3a and d). Amphiboles in the matrix (Amp2) (sample KB13-1) are chemically zoned, with pale-blue cores of barroisite and Mg-katophorite with compositions of Si = 6.87-7.38 pfu, Na_B = 1.16-1.48 pfu and X_{Mg} = 0.56-0.71, and riebeckite and magnesioriebeckite rims with Si = 7.54-7.96 pfu, Na_B = 1.59-1.95 pfu and X_{Mg} = 0.30-0.57 (Figs. 2c, 3 and 6a). The cores of amphiboles (Amp2) in the matrix (sample KB14-3) are classified as barroisite, with Si = 7.19-7.37 pfu, Na_B = 1.20-1.34 pfu and X_{Mg} = 0.64-0.67. The mantles are ferroglaucophane with Si = 7.96 pfu, Na_B = 1.94 pfu and X_{Mg} = 0.48, and the rims are riebeckite and magnesioriebeckite with Si = 7.78-7.96 pfu, Na_B = 1.60-1.94 pfu and X_{Mg} = 0.41-0.57 (Figs. 2b, 4 and 6a).

The cores of the zoned amphiboles (sample KB05) are magnesioriebeckite (Si = 7.71-7.94 pfu, Na_B = 1.53-1.87 pfu and X_{Mg} = 0.58-0.68), while the mantles are winchite with compositions of Si = 7.56-7.69 pfu, Na_B = 0.75-1.42 pfu and X_{Mg} = 0.69-0.79. The inner rims are magnesioriebeckite (Si = 7.84-7.94 pfu, Na_B = 1.65-1.79 pfu and X_{Mg} = 0.59-0.69) and the outermost rims are winchite with Si = 7.82-7.86 pfu, Na_B = 1.41-1.47 pfu and X_{Mg} = 0.68-0.73 (Figs. 2f, 5a-b and 6b).

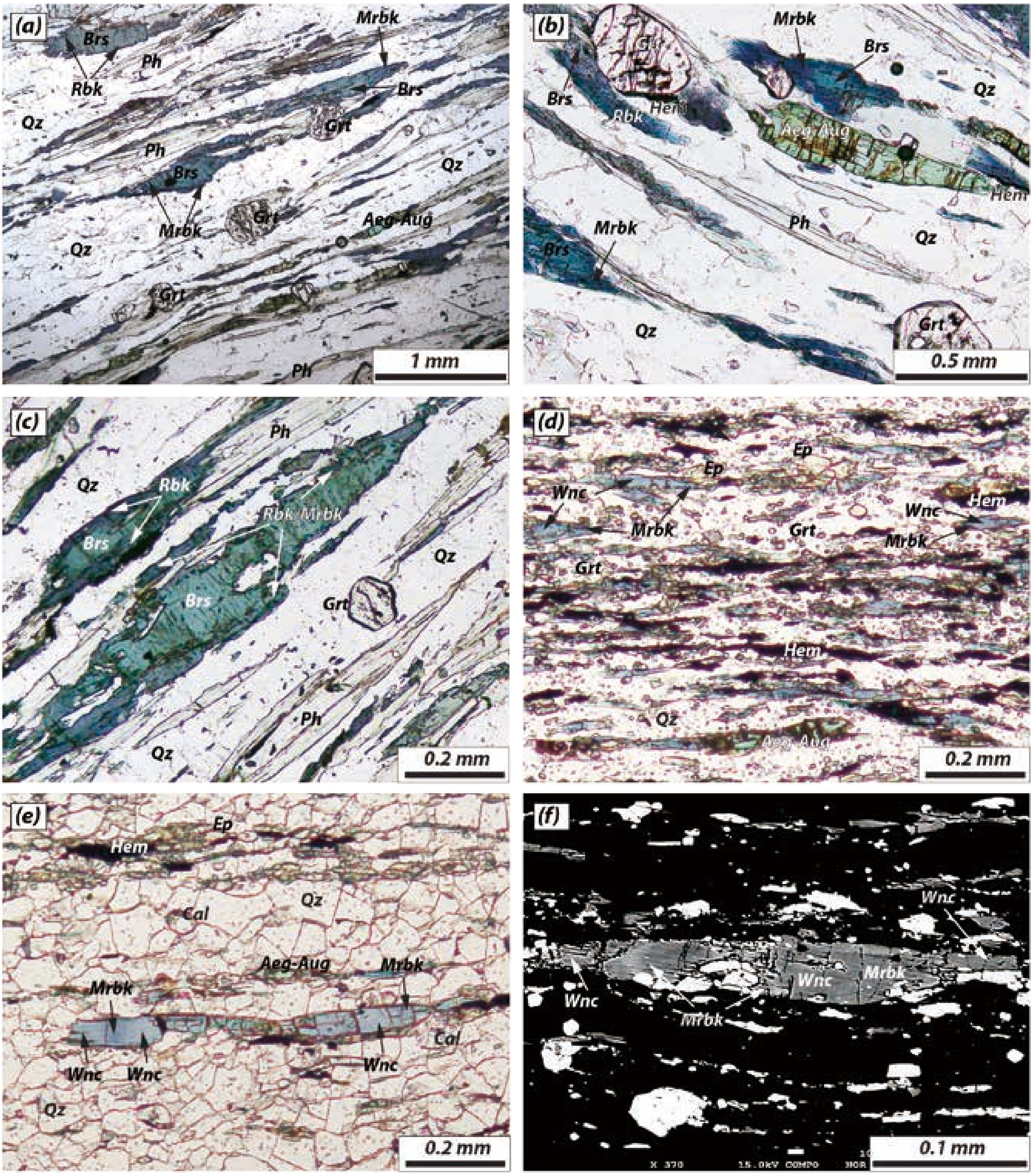

Fig. 2. Photomicrographs and a backscattered electron image (BEI) showing textural relationships of minerals in the garnet–aegirine-augite schists. (a) Zoned matrix amphiboles with barroisite cores and magnesioriebeckite rims, and other matrix minerals including garnet, aegirine-augite, phengite and quartz (KB13-1). (b) Matrix amphiboles with barroisite cores and magnesioriebeckite rims; other matrix minerals are garnet, aegirine-augite, phengite, hematite and quartz (KB14-3). (c) Zoned amphiboles in the matrix, with zoning from barroisite and Mg-katophorite cores to riebeckite and magnesioriebeckite rims; other matrix minerals are garnet, phengite and quartz (KB13-1). (d) Fine-grained garnets and schistosity-forming matrix amphibole (winchite core to magnesioriebeckite rim), aegirine-augite, epidote, hematite and quartz (KB05). (e) Zoned amphibole and other schistosity-forming minerals (aegirine-augite, epidote, hematite, calcite and quartz). (f) BEI of zoned amphibole in the matrix (KB05) showing magnesioriebeckite core, winchite mantle, magnesioriebeckite in the inner rim and winchite in the outermost rim.

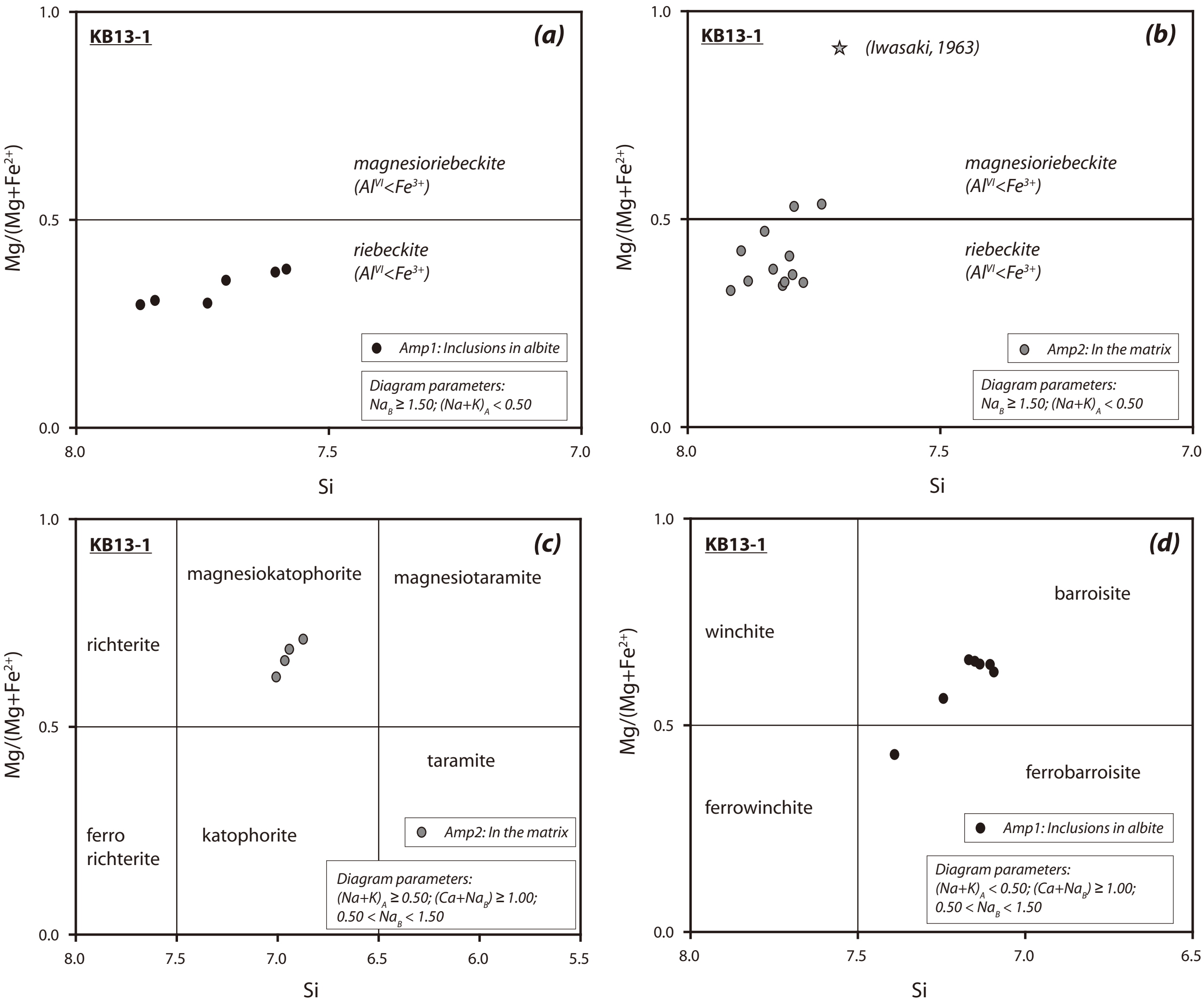

Fig. 3. Chemical compositions of amphiboles from the garnet–aegirine-augite schists (KB13-1), star indicates the magnesioriebeckite composition of Iwasaki (1963).

Discussion and Conclusions

Amphiboles in garnet–aegirine-augite schists in the Fukumandani Valley in the Bizan area show several modes of occurrence, and a wide range of chemical compositions (sodic and sodic-calcic) with complex zoning patterns. Amphiboles occurring in samples KB13-1 and KB14-3 are ferroglaucophane, magnesioriebeckite, riebeckite, Mg-katophorite, barroisite and ferrobarroisite, whereas those in sample KB05 are magnesioriebeckite, winchite and barroisite.

Iwasaki (1963) reported large crystals of alkali amphiboles from the spotted schist zone, which were strongly zoned from nearly colorless cores to colored rims. He reported that the rims of these amphiboles were magnesioriebeckite (Si = 7.70 pfu, $Na_B = 1.50$ pfu and $X_{Mg} = 0.91$). However, Iwasaki (1963) did not report the compositions of the cores of the strongly zoned amphiboles. In this study we identified and described three zones (core, mantle and rim) in the amphiboles, on the basis of chemical compositions. The cores and the mantles of the zoned amphiboles are ferrobarroisite / barroisite / Mg-katophorite (KB13-1 and KB14-3) with Si = 6.87-7.39 pfu, $Na_B = 1.16$-1.49 pfu and $X_{Mg} = 0.43$-0.71, and ferroglaucophane with Si = 7.96 pfu, $Na_B = 1.94$ pfu and $X_{Mg} = 0.48$, respectively. The rebeckite / magnesioriebeckite rims have similar Si contents (7.54-7.94 pfu), slightly higher Na_B (1.53-1.87 pfu), and lower X_{Mg} (0.58-0.68) than the magnesioriebeckite rim compositions reported by Iwasaki (1963). We have also recognized another type of amphibole zoning (KB05), with a core consisting of magnesioriebeckite zoned to a winchite mantle, passing through a magnesioriebeckite inner rim to winchite in the outermost rim. These features suggest that some fluctuations of *P*-*T* conditions may have occurred during the metamorphism of the garnet–aegirine-augite schists in the Bizan area.

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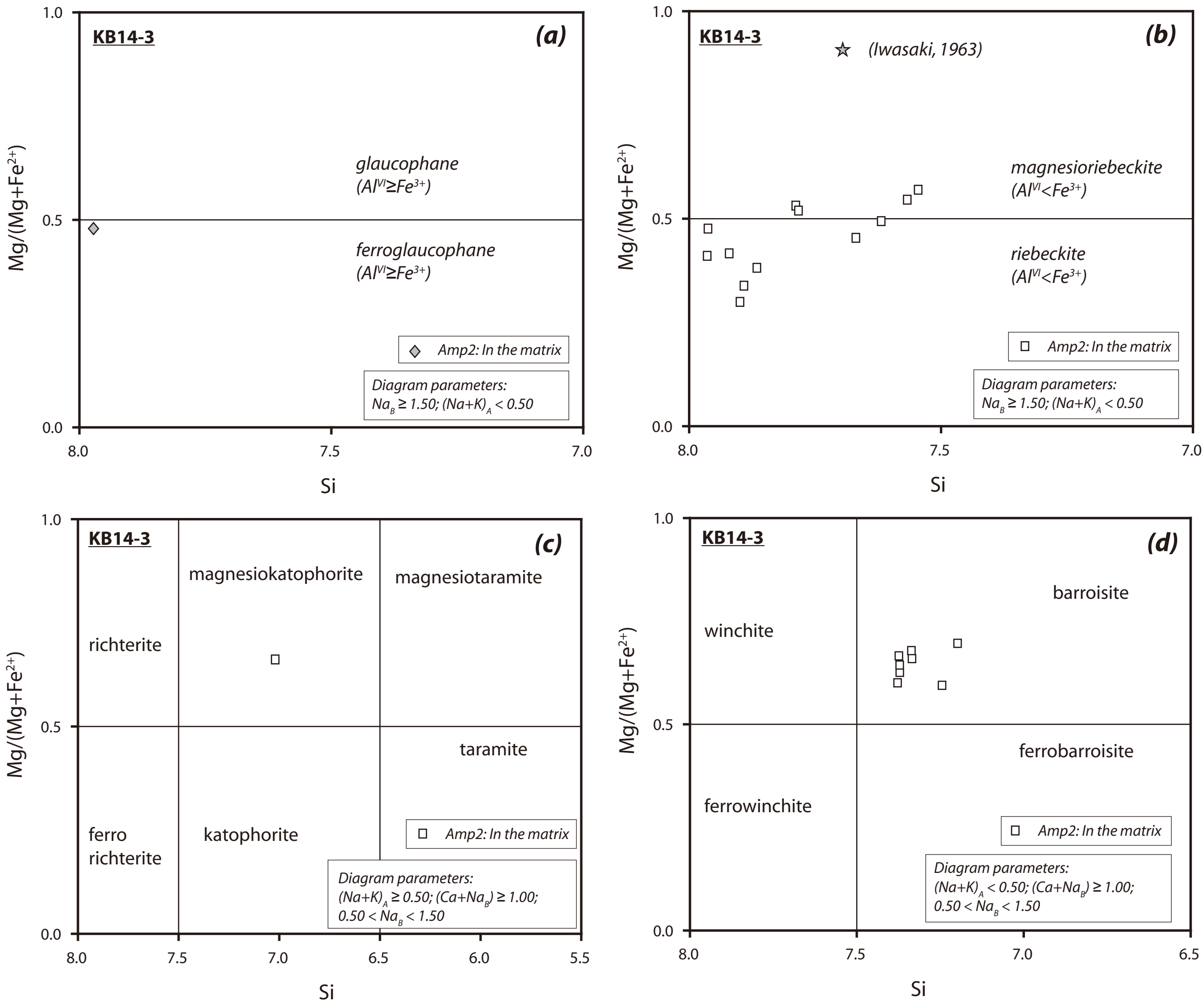

Fig. 4. Chemical compositions of amphiboles from the garnet–aegirine-augite schists (KB14-3), star indicates the magnesioriebeckite composition of Iwasaki (1963).

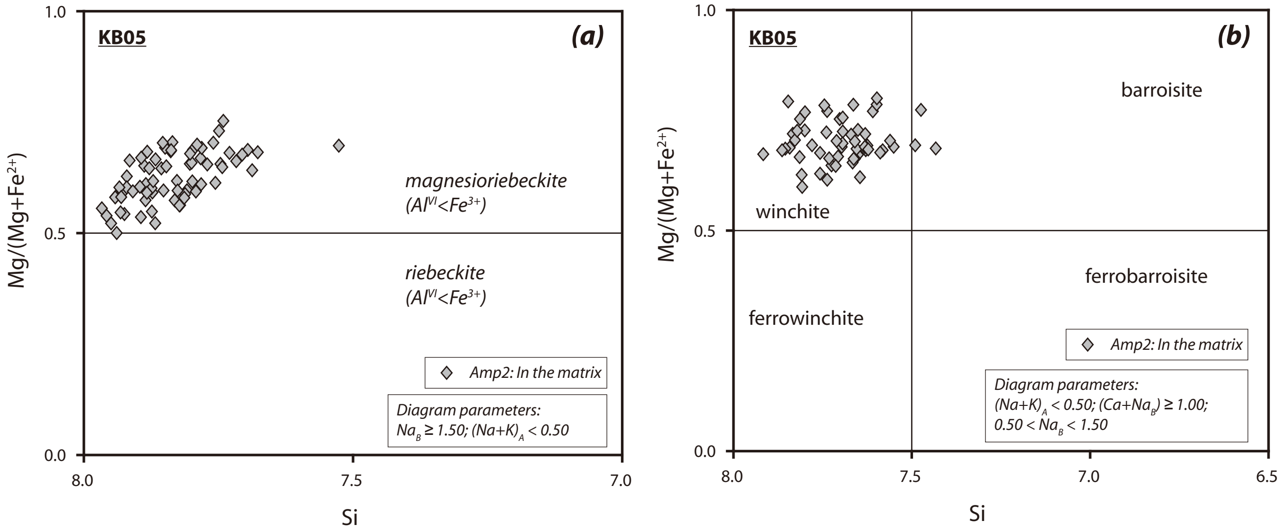

Fig. 5. Chemical compositions of amphiboles from the garnet–aegirine-augite schists (KB05).

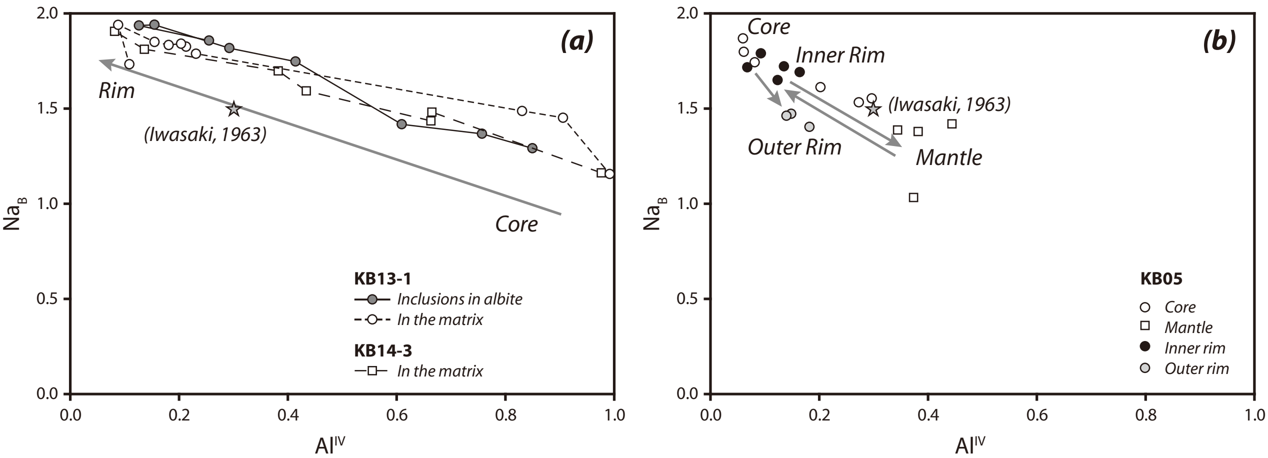

Fig. 6. Zoning profile of amphiboles from the garnet–aegirine-augite schists in the Bizan area. (a) KB13-1 and KB14-3 and (b) KB05. Star: magnesioriebeckite composition of Iwasaki (1963)

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（要　旨）

貝沼雅亮・高須　晃・Kabir Md. Fazle，2012 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角閃石．島根大学地球資源環境学研究報告，31，23-32.

四国東部眉山地域の三波川変成帯は，主として泥質片岩，塩基性片岩および珪質片岩が分布する．その他にざくろ石藍閃石片岩の薄層が局所的に分布する．本研究地域の点紋帯と無点紋帯において，ざくろ石－エジリン-オージャイト片岩の薄層が確認された．この結晶片岩は，主に石英とフェンジャイトからなり，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，マグネシオカトホル閃石，ウィンチ閃石，バロア閃石，鉄バロア閃石），ざくろ石，エジリン-オージャイトおよび曹長石を含む．また，微量の赤鉄鉱，緑泥石，緑簾石，方解石及びチタン石を含む．ざくろ石－エジリン-オージャイト片岩中の角閃石は，曹長石斑状変晶中の包有物としての産状（Amp1）と，基質中の産状（Amp2）の二種がみられる．角閃石には二種類の累帯構造が確認される．第一は，コアがバロア閃石または鉄バロア閃石，マントルが鉄藍閃石，そしてリムがリーベック閃石またはマグネシオリーベック閃石からなる累帯構造であり，第二は，コアがマグネシオリーベック閃石，マントルがウィンチ閃石，インナーリムがマグネシオリーベック閃石，そしてアウターリムがウィンチ閃石からなる累帯構造である．Iwasaki（1963）は，眉山地域のざくろ石とエジリン-オージャイトを含む結晶片岩中にマグネシオリーベック閃石のリムをもつ角閃石の累帯構造を記載したが，本研究の角閃石の累帯構造は，Iwasaki（1963）に記載されていない新しいタイプのものであることが判明した．すなわち，コアからリムへマグネシオリーベック閃石－ウィンチ閃石－マグネシオリーベック閃石－ウィンチ閃石の累帯構造であり，これは変成作用継続中に P-T 条件の繰り返し変動があった可能性を示す．

Table 1. Representative chemical compositions of amphiboles from the garnet–aegirine-augite schists.

Sample	KB 13-1																		
Analysis	213	214	215	216	217	218	219	220	221	222	223	224	225	226	7	8	16	23	92
	Amp1	Amp1	Amp1	Amp1	Amp1	Amp1	Amp1	Amp1	Amp1	Amp1	Amp1	Amp1	Amp1	Amp1	Amp2	Amp2	Amp2	Amp2	Amp2
	Rbk	Rbk	Rbk	Rbk	Rbk	Fbrs	Brs	Brs	Brs	Mg-Rbk	Brs	Brs	Brs	Rbk	Rbk	Rbk	Rbk	Rbk	Rbk
	Rim	←	←	←	←	←	←	Core	Core	→	→	→	→	Rim	Core	Rim	Rim	Rim	
SiO_2	51.12	53.25	53.02	51.77	51.37	49.06	48.92	48.40	48.58	48.83	48.65	48.18	48.12	51.54	53.88	53.55	52.55	53.33	52.21
TiO_2	0.03	0.05	0.04	0.06	0.04	0.09	0.13	0.16	0.14	0.13	0.15	0.16	0.18	0.12	0.06	0.05	0.01	0.03	0.05
Al_2O_3	3.55	5.52	5.67	6.16	6.57	6.42	7.06	7.59	8.04	8.64	8.22	8.25	7.97	7.04	5.05	5.46	3.57	6.07	4.01
FeO*	29.07	26.30	26.08	24.95	25.06	23.80	21.47	18.83	18.73	18.25	18.65	19.51	20.24	24.35	22.69	25.82	26.27	25.34	26.53
MnO	0.44	0.29	0.28	0.36	0.47	0.61	0.67	0.93	0.98	1.14	0.96	0.99	1.01	0.33	0.34	0.33	0.45	0.24	0.51
MgO	3.89	3.95	4.08	4.74	5.05	6.15	8.00	9.37	9.26	8.94	8.96	8.70	8.55	5.04	6.80	4.85	5.71	4.63	5.05
CaO	0.88	0.41	0.39	1.15	1.60	3.60	3.98	4.47	4.18	3.02	3.25	3.32	3.47	1.53	0.97	0.61	1.01	0.34	0.90
Na_2O	6.68	6.93	7.04	6.67	6.47	5.71	5.66	5.63	6.06	6.60	6.47	6.45	6.44	6.60	7.12	7.55	6.98	7.10	7.06
K_2O	0.12	0.07	0.05	0.17	0.23	0.34	0.31	0.36	0.28	0.29	0.23	0.30	0.31	0.16	0.12	0.08	0.09	0.07	0.10
Total	95.77	96.77	96.65	96.03	96.86	95.76	96.20	95.74	96.25	95.83	95.54	95.85	96.29	96.69	97.03	98.30	96.64	97.15	96.42
Cations on the basis of 23 oxygens																			
Si	7.74	7.87	7.84	7.70	7.59	7.39	7.24	7.15	7.14	7.16	7.17	7.11	7.09	7.61	7.84	7.81	7.80	7.81	7.79
Ti	0.00	0.01	0.00	0.01	0.00	0.01	0.01	0.02	0.02	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.00	0.00	0.01
Al	0.63	0.96	0.99	1.08	1.14	1.14	1.23	1.32	1.39	1.49	1.43	1.43	1.39	1.22	0.87	0.94	0.62	1.05	0.71
Fe^{3+}	1.60	1.15	1.16	1.17	1.27	1.16	1.30	1.24	1.20	1.28	1.28	1.37	1.39	1.13	1.09	1.09	1.44	1.20	1.35
Fe^{2+}	2.08	2.10	2.07	1.94	1.82	1.84	1.36	1.08	1.10	0.96	1.02	1.04	1.10	1.87	1.67	2.06	1.82	1.90	1.96
Mn	0.06	0.04	0.04	0.05	0.06	0.08	0.08	0.12	0.12	0.14	0.12	0.12	0.13	0.04	0.04	0.04	0.06	0.03	0.06
Mg	0.88	0.87	0.90	1.05	1.11	1.38	1.76	2.06	2.03	1.95	1.97	1.91	1.88	1.11	1.48	1.05	1.26	1.01	1.12
Ca	0.14	0.06	0.06	0.18	0.25	0.58	0.63	0.71	0.66	0.47	0.51	0.52	0.55	0.24	0.15	0.10	0.16	0.05	0.14
Na	1.96	1.99	2.02	1.93	1.85	1.67	1.62	1.61	1.73	1.88	1.85	1.84	1.84	1.89	2.01	2.13	2.01	2.01	2.04
K	0.02	0.01	0.01	0.03	0.04	0.06	0.06	0.07	0.05	0.05	0.04	0.06	0.06	0.03	0.02	0.01	0.02	0.01	0.02
Total	15.12	15.06	15.09	15.13	15.15	15.31	15.31	15.39	15.43	15.40	15.40	15.42	15.45	15.16	15.18	15.24	15.19	15.08	15.21

**Total Fe as FeO*

Sample	KB 13-1							KB 14-3											
Analysis	93	94	96	97	98	99	145	22	32	144	15	76	85	86	75	77	74	78	26
	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2
	Mg-Rbk	Rbk	Mg-Rbk	Rbk	Rbk	Rbk	Rbk	Mg-Ktp	Mg-Ktp	Mg-Ktp	Mg-Ktp	Mg-Ktp	Brs	Brs	Mg-Rbk	Rbk	Rbk	Rbk	Rbk
								Core	Core		Core								
SiO_2	53.33	52.99	53.44	51.66	53.36	53.24	53.28	47.61	46.58	46.67	47.07	47.44	50.32	50.11	51.12	51.87	53.04	54.31	53.40
TiO_2	0.05	0.01	0.05	0.03	0.05	0.03	0.11	0.24	0.14	0.18	0.20	0.18	0.11	0.12	0.11	0.09	0.02	0.03	0.05
Al_2O_3	5.19	5.41	5.38	3.43	5.63	5.08	5.18	8.24	8.35	7.74	7.38	7.71	5.29	5.47	5.20	4.73	3.72	5.11	3.62
FeO*	21.55	24.61	20.76	27.86	24.60	25.31	22.26	18.44	18.89	19.42	20.42	18.56	22.00	20.76	21.74	24.03	25.89	23.55	27.31
MnO	0.44	0.26	0.42	0.56	0.22	0.24	0.46	1.20	1.11	0.93	0.71	0.97	0.86	0.82	0.61	0.51	0.46	0.39	0.28
MgO	7.45	4.87	7.60	4.66	5.24	4.59	6.24	10.20	9.95	9.49	9.20	9.93	9.00	9.46	7.93	7.03	5.51	5.89	4.84
CaO	1.12	0.46	1.07	1.32	0.47	0.39	1.69	5.20	4.73	4.80	5.28	5.29	3.33	3.61	2.58	1.93	1.20	0.61	0.69
Na_2O	6.88	7.25	6.94	6.42	7.27	7.28	6.47	5.92	6.04	5.90	5.41	5.55	6.25	6.09	6.37	6.67	6.89	7.08	7.17
K_2O	0.13	0.06	0.12	0.15	0.08	0.05	0.15	0.53	0.50	0.42	0.50	0.59	0.32	0.34	0.29	0.21	0.11	0.04	0.05
Total	96.15	95.93	95.76	96.08	96.91	96.20	95.84	97.58	96.29	95.55	96.17	96.22	97.47	96.77	95.94	97.08	96.83	97.02	97.41
Cations on the basis of 23 oxygens																			
Si	7.79	7.88	7.82	7.77	7.83	7.91	7.89	6.94	6.87	6.97	7.01	7.02	7.33	7.34	7.56	7.62	7.86	7.92	7.89
Ti	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.03	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.01
Al	0.89	0.95	0.93	0.61	0.97	0.89	0.90	1.42	1.45	1.36	1.30	1.35	0.91	0.94	0.91	0.82	0.65	0.88	0.63
Fe^{3+}	1.19	1.04	1.10	1.52	1.13	1.05	0.87	1.25	1.45	1.34	1.30	1.18	1.53	1.44	1.24	1.38	1.24	1.08	1.30
Fe^{2+}	1.44	2.01	1.44	1.98	1.89	2.10	1.89	1.00	0.88	1.08	1.24	1.11	1.15	1.11	1.45	1.57	1.97	1.79	2.07
Mn	0.05	0.03	0.05	0.07	0.03	0.03	0.06	0.15	0.14	0.12	0.09	0.12	0.11	0.10	0.08	0.06	0.06	0.05	0.03
Mg	1.62	1.08	1.66	1.05	1.15	1.02	1.38	2.22	2.19	2.11	2.04	2.19	1.96	2.06	1.75	1.54	1.22	1.28	1.07
Ca	0.18	0.07	0.17	0.21	0.07	0.06	0.27	0.81	0.75	0.77	0.84	0.84	0.52	0.57	0.41	0.30	0.19	0.10	0.11
Na	1.95	2.09	1.97	1.87	2.07	2.10	1.86	1.67	1.73	1.71	1.56	1.59	1.77	1.73	1.83	1.90	1.98	2.00	2.05
K	0.02	0.01	0.02	0.03	0.01	0.01	0.03	0.10	0.09	0.08	0.09	0.11	0.06	0.06	0.05	0.04	0.02	0.01	0.01
Total	15.14	15.17	15.16	15.11	15.15	15.17	15.15	15.58	15.57	15.56	15.50	15.54	15.34	15.35	15.29	15.24	15.19	15.11	15.16

**Total Fe as FeO*

Sample	KB 14-3												KB 05						
Analysis	29	42	43	44	59	60	87	88	27	28	57	58	10	11	12	13	14	15	16
	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2
	Rbk	Rbk	Mg-Rbk	Mg-Rbk	Fgl	Mg-Rbk	Brs	Brs	Brs	Brs	Brs	Brs	Wnc	Wnc	Mg-Rbk	Mg-Rbk	Mg-Rbk	Wnc	Wnc
													Rim	←	←	←	←	←	←
SiO_2	52.85	54.28	51.71	53.33	55.09	53.10	49.84	50.29	48.51	49.90	49.10	50.16	52.70	54.19	54.84	54.41	54.66	52.83	52.29
TiO_2	0.03	0.05	0.10	0.08	0.01	0.03	0.14	0.23	0.17	0.12	0.16	0.14	0.01	0.00	0.00	0.05	0.00	0.04	0.03
Al_2O_3	5.21	5.11	5.09	4.61	6.51	3.64	5.66	5.57	6.71	5.45	6.27	5.70	2.46	2.68	3.34	3.00	3.05	4.53	5.39
FeO*	25.83	23.14	22.35	21.98	20.18	23.12	21.19	22.33	20.85	21.58	19.09	19.98	19.77	19.84	20.38	22.18	23.18	18.99	17.78
MnO	0.28	0.28	0.63	0.45	0.39	0.58	0.80	0.77	0.68	0.73	0.94	0.75	0.81	0.85	0.54	0.60	0.40	0.64	0.69
MgO	4.12	5.83	8.11	7.69	6.70	7.70	8.64	8.22	8.38	8.65	10.26	9.45	10.88	10.37	9.20	8.57	7.81	10.35	10.67
CaO	0.46	0.38	2.48	1.45	0.41	2.52	3.40	3.29	4.72	3.60	5.10	4.20	3.71	3.37	1.33	1.22	0.84	3.49	4.31
Na_2O	7.03	7.20	6.33	6.80	7.03	5.95	6.16	6.20	5.35	5.65	5.47	5.47	5.25	5.63	6.69	6.87	6.97	5.56	5.30
K_2O	0.08	0.03	0.28	0.15	0.07	0.20	0.40	0.34	0.51	0.34	0.47	0.40	0.07	0.05	0.07	0.05	0.04	0.10	0.17
Total	95.89	96.30	97.07	96.53	96.40	96.85	96.22	97.24	95.88	96.01	96.86	96.26	95.67	96.98	96.39	96.95	96.96	96.54	96.63
Cations on the basis of 23 oxygens																			
Si	7.90	7.96	7.54	7.79	7.96	7.78	7.37	7.38	7.24	7.37	7.19	7.37	7.69	7.81	7.92	7.87	7.93	7.62	7.55
Ti	0.00	0.01	0.01	0.01	0.00	0.00	0.02	0.03	0.02	0.01	0.02	0.02	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Al	0.92	0.88	0.88	0.79	1.11	0.63	0.99	0.96	1.18	0.95	1.08	0.99	0.42	0.45	0.57	0.51	0.52	0.77	0.92
Fe^{3+}	1.08	1.01	1.40	1.21	0.86	1.28	1.32	1.37	1.13	1.45	1.25	1.27	1.52	1.29	1.29	1.41	1.39	1.32	1.13
Fe^{2+}	2.15	1.83	1.33	1.47	1.58	1.55	1.29	1.37	1.47	1.21	1.09	1.18	0.89	1.10	1.17	1.27	1.42	0.98	1.02
Mn	0.03	0.03	0.08	0.06	0.05	0.07	0.10	0.10	0.09	0.09	0.12	0.09	0.10	0.10	0.07	0.07	0.05	0.08	0.08
Mg	0.92	1.28	1.76	1.67	1.44	1.68	1.90	1.80	1.87	1.91	2.24	2.07	2.37	2.23	1.98	1.85	1.69	2.23	2.30
Ca	0.07	0.06	0.39	0.23	0.06	0.40	0.54	0.52	0.76	0.57	0.80	0.66	0.58	0.52	0.21	0.19	0.13	0.54	0.67
Na	2.04	2.05	1.79	1.92	1.97	1.69	1.76	1.76	1.55	1.62	1.55	1.56	1.49	1.57	1.87	1.93	1.96	1.56	1.48
K	0.01	0.01	0.05	0.03	0.01	0.04	0.07	0.06	0.10	0.06	0.09	0.08	0.01	0.01	0.01	0.01	0.01	0.02	0.03
Total	15.13	15.11	15.23	15.18	15.04	15.12	15.37	15.34	15.40	15.25	15.43	15.30	15.08	15.10	15.09	15.12	15.09	15.11	15.18

**Total Fe as FeO*

Table 1. (continued)

Sample	KB 05																		
Analysis	17	18	19	20	21	22	25	24	26	27	36	37	38	47	48	49	50	51	52
	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2
	Wnc	Mg-Rbk	Wnc	Mg-Rbk	Mg-Rbk	Mg-Rbk	Mg-Rbk	Mg-Rbk	Wnc	Wnc	Mg-Rbk	Brs	Brs	Mg-Rbk	Mg-Rbk	Mg-Rbk	Mg-Rbk	Mg-Rbk	Mg-Rbk
	←	←	←	Core	→	→	→	→	→	Rim									
SiO_2	52.32	54.16	53.75	55.28	54.05	53.77	54.16	54.35	52.51	54.18	54.38	50.77	51.33	54.48	54.20	54.65	55.22	54.39	55.20
TiO_2	0.02	0.03	0.05	0.02	0.05	0.02	0.03	0.03	0.01	0.02	0.01	0.01	0.00	0.00	0.01	0.01	0.03	0.01	0.00
Al_2O_3	5.21	5.47	2.03	4.35	4.69	4.92	2.61	2.67	3.16	2.32	3.87	5.43	5.46	3.17	5.54	5.26	4.49	5.66	5.37
FeO*	17.89	17.41	13.71	20.18	20.09	19.46	23.79	20.27	18.28	16.52	23.41	18.47	17.91	22.96	19.79	19.89	21.01	19.35	19.02
MnO	0.64	0.52	1.20	0.35	0.32	0.46	0.53	0.53	0.90	1.05	0.48	0.65	0.65	0.43	0.46	0.39	0.31	0.44	0.32
MgO	10.55	9.92	14.52	8.75	8.91	9.01	7.76	9.80	11.53	12.53	7.32	10.47	10.60	7.58	9.37	8.47	8.12	9.07	8.91
CaO	4.07	2.16	8.85	1.45	2.12	2.59	1.38	2.38	6.19	5.29	0.45	4.70	4.60	1.12	2.24	1.34	1.11	1.94	1.31
Na_2O	5.50	6.36	2.43	6.49	6.32	6.12	6.62	5.92	4.17	4.20	7.34	5.17	5.09	6.70	6.39	6.51	6.93	6.62	6.66
K_2O	0.09	0.07	0.12	0.03	0.07	0.07	0.03	0.07	0.14	0.07	0.05	0.13	0.13	0.05	0.07	0.05	0.05	0.07	0.06
Total	96.28	96.09	96.67	96.89	96.60	96.42	96.91	96.02	96.89	96.17	97.29	95.81	95.76	96.48	98.07	96.56	97.27	97.55	96.86
Cations on the basis of 23 oxygens																			
Si	7.58	7.78	7.74	7.93	7.81	7.79	7.90	7.89	7.63	7.80	7.87	7.43	7.49	7.95	7.69	7.85	7.93	7.76	7.89
Ti	0.00	0.00	0.01	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	0.00	0.00
Al	0.89	0.93	0.34	0.73	0.80	0.84	0.45	0.46	0.54	0.39	0.66	0.94	0.94	0.55	0.93	0.89	0.76	0.95	0.90
Fe^{3+}	1.12	1.04	0.74	1.15	1.13	1.03	1.45	1.33	1.07	1.19	1.39	1.23	1.18	1.30	1.24	1.16	1.08	1.09	1.06
Fe^{2+}	1.05	1.05	0.91	1.27	1.30	1.33	1.46	1.13	1.15	0.80	1.44	1.03	1.01	1.50	1.10	1.23	1.44	1.21	1.21
Mn	0.08	0.06	0.15	0.04	0.04	0.06	0.07	0.06	0.11	0.13	0.06	0.08	0.08	0.05	0.06	0.05	0.04	0.05	0.04
Mg	2.28	2.12	3.12	1.87	1.92	1.95	1.69	2.12	2.50	2.69	1.58	2.29	2.30	1.65	1.98	1.82	1.74	1.93	1.90
Ca	0.63	0.33	1.37	0.22	0.33	0.40	0.22	0.37	0.96	0.82	0.07	0.74	0.72	0.18	0.34	0.21	0.17	0.30	0.20
Na	1.55	1.77	0.68	1.80	1.77	1.72	1.87	1.67	1.17	1.17	2.06	1.47	1.44	1.89	1.76	1.81	1.93	1.83	1.85
K	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.03	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
Total	15.19	15.11	15.07	15.03	15.11	15.14	15.09	15.04	15.16	15.00	15.14	15.23	15.18	15.08	15.11	15.03	15.11	15.14	15.06

*Total Fe as FeO

Sample	KB 05																		
Analysis	53	54	57	58	59	60	61	62	63	64	65	66	1	6	9	10	12	14	15
	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2
	Mg-Rbk	Mg-Rbk	Wnc	Wnc	Wnc	Wnc	Wnc	Wnc	Wnc	Mg-Rbk	Wnc	Wnc	Wnc	Mg-Rbk	Mg-Rbk	Mg-Rbk	Mg-Rbk	Mg-Rbk	Mg-Rbk
	Rim	←	←	←	←	Core	→	→	→	→	→	Rim		Core	→	→	→	→	→
SiO_2	54.12	53.74	52.97	53.72	54.10	53.71	52.95	53.21	53.69	54.49	54.52	53.25	52.67	53.68	53.12	53.35	54.75	54.46	53.88
TiO_2	0.00	0.04	0.02	0.01	0.03	0.04	0.02	0.03	0.02	0.01	0.01	0.02	0.01	0.00	0.06	0.00	0.04	0.02	0.00
Al_2O_3	2.37	2.36	4.80	4.79	4.57	4.69	4.80	3.83	3.48	2.60	2.10	2.98	2.58	2.77	2.62	2.58	3.82	4.08	4.96
FeO*	20.31	24.23	19.13	18.37	18.64	18.20	18.58	20.38	21.50	19.19	17.96	18.26	20.21	20.99	24.13	23.87	21.01	19.20	17.74
MnO	0.82	0.45	0.62	0.62	0.64	0.59	0.64	0.55	0.49	0.85	0.87	1.07	0.86	0.66	0.57	0.57	0.39	0.48	0.48
MgO	10.48	7.23	10.45	10.14	10.56	10.27	10.15	10.05	9.37	10.41	11.87	11.40	10.67	9.80	7.62	7.54	8.68	9.70	9.73
CaO	3.20	1.04	4.25	3.27	3.31	3.29	3.52	3.96	3.30	2.92	4.62	5.25	3.54	1.82	1.06	1.00	1.48	2.36	2.97
Na_2O	5.61	6.83	5.21	5.97	5.76	5.78	5.69	5.17	5.56	5.65	4.88	4.61	5.46	6.36	6.57	6.63	6.34	5.99	6.05
K_2O	0.08	0.03	0.12	0.11	0.09	0.09	0.10	0.10	0.07	0.06	0.07	0.15	0.05	0.01	0.00	0.00	0.01	0.03	0.06
Total	96.99	95.95	97.55	97.00	97.70	96.66	96.47	97.28	97.48	96.19	96.89	97.01	96.05	96.09	95.75	95.54	96.52	96.32	95.86
Cations on the basis of 23 oxygens																			
Si	7.80	7.94	7.59	7.73	7.70	7.73	7.66	7.67	7.74	7.88	7.83	7.69	7.67	7.78	7.82	7.88	7.90	7.85	7.83
Ti	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	0.00	0.00
Al	0.40	0.41	0.81	0.81	0.77	0.80	0.82	0.65	0.59	0.44	0.36	0.51	0.44	0.47	0.45	0.45	0.65	0.69	0.85
Fe^{3+}	1.43	1.41	1.24	1.04	1.22	1.09	1.15	1.33	1.34	1.28	1.18	1.15	1.56	1.61	1.67	1.59	1.32	1.20	0.85
Fe^{2+}	1.02	1.59	1.06	1.17	1.00	1.11	1.10	1.13	1.25	1.04	0.98	1.05	0.90	0.94	1.30	1.36	1.22	1.12	1.30
Mn	0.10	0.06	0.08	0.08	0.08	0.07	0.08	0.07	0.06	0.10	0.11	0.13	0.11	0.08	0.07	0.07	0.05	0.06	0.06
Mg	2.25	1.59	2.23	2.17	2.24	2.20	2.19	2.16	2.01	2.25	2.54	2.46	2.32	2.12	1.67	1.66	1.87	2.08	2.11
Ca	0.49	0.16	0.65	0.50	0.50	0.51	0.55	0.61	0.51	0.45	0.71	0.81	0.55	0.28	0.17	0.16	0.23	0.36	0.46
Na	1.57	1.96	1.45	1.66	1.59	1.61	1.60	1.44	1.55	1.59	1.36	1.29	1.54	1.79	1.88	1.90	1.77	1.67	1.71
K	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.03	0.01	0.00	0.00	0.00	0.00	0.01	0.01
Total	15.07	15.13	15.12	15.18	15.11	15.14	15.16	15.07	15.07	15.05	15.08	15.13	15.10	15.07	15.04	15.06	15.00	15.04	15.18

*Total Fe as FeO

Sample	KB 05																		
Analysis	16	17	20	21	22	23	24	25	26	27	28	29	30	31	32	34	35	36	37
	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2
	Wnc	Wnc	Mg-Rbk	Wnc	Mg-Rbk	Wnc	Wnc	Wnc	Wnc	Mg-Rbk	Wnc	Wnc	Wnc	Mg-Rbk	Mg-Rbk	Wnc	Wnc	Mg-Rbk	Wnc
	→	→	→	→	→	→	→	→	Rim	Core	→	→	→	→	→	Rim		Core	→
SiO_2	53.59	53.46	54.06	53.72	53.73	52.97	52.51	53.01	53.49	54.12	53.14	53.21	54.32	54.28	54.50	54.81	54.73	55.09	54.98
TiO_2	0.01	0.03	0.03	0.00	0.08	0.01	0.00	0.03	0.05	0.02	0.07	0.03	0.04	0.00	0.00	0.00	0.00	0.03	0.01
Al_2O_3	4.71	5.06	4.85	4.39	4.66	4.71	4.78	4.97	3.74	4.00	4.30	3.84	3.50	3.26	2.95	2.75	2.23	2.81	2.85
FeO*	18.92	18.42	17.63	18.59	18.80	17.83	17.80	18.49	19.73	20.46	21.01	19.93	20.96	21.78	22.67	19.61	19.17	19.96	18.50
MnO	0.56	0.61	0.65	0.69	0.82	0.58	0.55	0.58	0.61	0.61	0.62	0.58	0.59	0.50	0.48	0.77	0.82	0.65	1.07
MgO	10.44	10.55	10.03	10.42	10.09	10.34	10.68	10.11	10.20	9.65	9.39	9.57	9.35	9.20	8.83	10.56	10.56	10.54	11.12
CaO	3.36	3.68	3.00	3.32	3.21	4.02	4.39	3.97	4.05	3.07	3.62	3.47	3.26	2.62	2.29	3.36	3.51	2.31	3.93
Na_2O	5.80	5.61	5.79	5.40	5.52	5.12	4.96	5.13	5.28	5.57	5.47	5.36	5.70	5.88	6.06	5.34	5.20	6.15	5.18
K_2O	0.06	0.06	0.05	0.06	0.05	0.08	0.08	0.09	0.03	0.06	0.07	0.05	0.02	0.05	0.03	0.02	0.05	0.03	0.06
Total	97.45	97.49	96.09	96.60	96.95	95.66	95.74	96.38	97.18	97.55	97.69	96.02	97.73	97.56	97.82	97.21	96.27	97.58	97.70
Cations on the basis of 23 oxygens																			
Si	7.66	7.63	7.80	7.71	7.70	7.71	7.63	7.66	7.71	7.74	7.65	7.76	7.81	7.80	7.83	7.84	7.92	7.84	7.83
Ti	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Al	0.79	0.85	0.83	0.74	0.79	0.81	0.82	0.85	0.63	0.67	0.73	0.66	0.59	0.55	0.50	0.46	0.38	0.47	0.48
Fe^{3+}	1.25	1.20	1.00	1.30	1.28	1.06	1.13	1.14	1.19	1.34	1.31	1.21	1.19	1.39	1.44	1.34	1.22	1.44	1.23
Fe^{2+}	1.01	1.00	1.13	0.93	0.98	1.11	1.03	1.10	1.19	1.11	1.22	1.22	1.33	1.22	1.28	1.01	1.09	0.93	0.98
Mn	0.07	0.07	0.08	0.08	0.10	0.07	0.07	0.07	0.07	0.07	0.08	0.07	0.07	0.06	0.06	0.09	0.10	0.08	0.13
Mg	2.22	2.24	2.16	2.23	2.15	2.24	2.31	2.18	2.19	2.06	2.01	2.08	2.00	1.97	1.89	2.25	2.28	2.24	2.36
Ca	0.51	0.56	0.46	0.51	0.49	0.63	0.68	0.62	0.63	0.47	0.56	0.54	0.50	0.40	0.35	0.51	0.54	0.35	0.60
Na	1.61	1.55	1.62	1.50	1.53	1.44	1.40	1.44	1.48	1.54	1.53	1.51	1.59	1.64	1.69	1.48	1.46	1.70	1.43
K	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.01	0.01	0.01
Total	15.13	15.13	15.09	15.02	15.03	15.08	15.09	15.07	15.11	15.03	15.10	15.06	15.09	15.05	15.05	15.00	15.01	15.05	15.04

*Total Fe as FeO

Table 1. (continued)

Sample	KB 05													
Analysis	38	39	40	43	2	6	8	9	10	20	21	24	28	29
	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2	Amp2
	Wnc	Mg-Rbk	Wnc	Wnc	Wnc	Mg-Rbk	Mg-Rbk	Mg-Rbk	Mg-Rbk	Wnc	Mg-Rbk	Mg-Rbk	Mg-Rbk	Mg-Rbk
	→	→	→	Mantle										
SiO_2	54.29	54.60	54.35	53.19	51.93	53.31	54.32	54.34	54.15	52.15	54.40	52.00	54.11	53.95
TiO_2	0.00	0.00	0.00	0.04	0.05	0.02	0.00	0.02	0.02	0.02	0.00	0.00	0.00	0.01
Al_2O_3	2.94	2.72	2.67	2.82	5.06	4.50	2.87	2.93	3.33	2.97	3.10	5.94	2.56	3.12
FeO*	18.50	19.07	18.86	18.44	18.25	18.56	22.03	22.38	19.75	17.49	20.31	19.23	22.88	22.68
MnO	0.86	0.87	0.93	0.97	0.66	0.60	0.45	0.44	0.68	1.08	0.56	2.42	0.48	0.42
MgO	11.08	10.17	11.24	10.95	10.42	10.05	8.32	8.07	9.50	11.84	9.63	8.50	8.48	8.03
CaO	3.47	2.87	4.60	5.12	3.71	3.00	1.29	0.84	2.24	6.16	1.79	2.25	1.14	0.97
Na_2O	5.33	5.70	4.90	4.44	5.47	5.64	6.42	6.60	5.97	4.00	6.27	6.04	6.67	6.71
K_2O	0.04	0.02	0.05	0.07	0.09	0.06	0.00	0.01	0.02	0.10	0.02	0.03	0.01	0.01
Total	96.50	96.03	97.61	96.03	95.64	95.74	95.71	95.62	95.65	95.80	96.08	96.40	96.33	95.89
Cations on the basis of 23 oxygens														
Si	7.80	7.92	7.78	7.76	7.56	7.731	7.942	7.943	7.880	7.631	7.869	7.528	7.876	7.887
Ti	0.00	0.00	0.00	0.00	0.01	0.002	0.000	0.002	0.002	0.002	0.000	0.000	0.000	0.002
Al	0.50	0.47	0.45	0.48	0.87	0.770	0.494	0.504	0.571	0.511	0.529	1.014	0.439	0.537
Fe^{3+}	1.34	1.20	1.21	1.12	1.28	1.236	1.398	1.469	1.279	1.139	1.419	1.534	1.567	1.478
Fe^{2+}	0.88	1.11	1.05	1.13	0.94	1.016	1.296	1.267	1.125	1.000	1.038	0.794	1.218	1.295
Mn	0.10	0.11	0.11	0.12	0.08	0.074	0.056	0.054	0.083	0.133	0.069	0.297	0.059	0.052
Mg	2.37	2.20	2.40	2.38	2.26	2.172	1.814	1.759	2.060	2.583	2.077	1.833	1.840	1.749
Ca	0.53	0.45	0.71	0.80	0.58	0.466	0.201	0.131	0.349	0.965	0.278	0.348	0.178	0.151
Na	1.48	1.60	1.36	1.26	1.54	1.585	1.820	1.869	1.683	1.134	1.757	1.695	1.883	1.903
K	0.01	0.00	0.01	0.01	0.02	0.011	0.001	0.003	0.004	0.019	0.003	0.005	0.002	0.002
Total	15.03	15.05	15.08	15.07	15.14	15.06	15.02	15.00	15.04	15.12	15.04	15.05	15.06	15.06

**Total Fe as FeO*