Bulletin of the Geological Survey of Japan, vol. 52 (9), p. 425–443, 2001

Notes and Comments

Chemical compositions of amphiboles in hematite-bearing schists from the Saruta-gawa area in the Sanbagawa belt, central Shikoku, Japan

Yasuyuki BANNO[1]

Yasuyuki BANNO (2001) Chemical compositions of amphiboles in hematite-bearing schists from the Saruta-gawa area in the Sanbagawa belt, central Shikoku, Japan. *Bull. Geol. Surv. Japan,* vol. 52 (9), p. 425–443, 3 figs, 10 tables.

Abstract: Amphibole and other minerals in the hematite-bearing basic and quartz schists from the Saruta-gawa area in the Sanbagawa belt, central Shikoku were analyzed by the electron microprobe. The data presented comprise 221 analyses of amphibole, and 90 analyses of epidote, chlorite, garnet, muscovite, albite, hematite, magnetite and stilpnomelane. All the minerals in this study occur from the hematite-bearing schists in the albite-biotite zone of high metamorphic grade. These chemical data were used in order to discuss the Sanbagawa retrograde metamorphism in the Saruta-gawa area (Banno, 2000).

1. Introduction

The Sanbagawa belt is a regional coherent high-P/T metamorphic belt that extends from east to west for about 800 km in the Southwest Japan. The peak metamorphic condition has been estimated in many previous studies, and characteristics of the metamorphic field gradient were compiled by Banno and Sakai (1989) and Enami *et al.* (1994).

The chemistry of amphibole in hematite-bearing basic and quartz schists of the Sanbagawa belt can be used as a sensitive indicator of metamorphic grade (Otsuki and Banno, 1990; Enami *et al.,* 1994). Otsuki and Banno (1990) studied the compositional zonation of amphibole crystals in the hematite-bearing basic schists in the Asemi-gawa area, central Shikoku, and showed that the zoned amphibole exhibited decreasing Al_2O_3 contents towards the crystal margin and was usually rimmed with actinolite. They proposed the phase relation of the amphiboles associated with chlorite, epidote, muscovite, albite, quartz and hematite, and considered that the zonal structure indicates the rapid pressure release during the early stage of retrograde metamorphism. The amphibole in the hematite-bearing basic schists from the Saruta-gawa area located in 8 km north of the Asemi-gawa area (Fig. 1), however, has usually a rim of retrograde sodic amphibole instead of actinolite (Hara *et al.,* 1990), and Banno (2000) showed that the Saruta-gawa samples experienced retrograde metamorphism under higher P/T condition than the Asemi-gawa samples. Thus, the compositional trend of zoned amphiboles in hematite-bearing schists is important for understanding retrograde metamorphism, although, in the literature, few analytical data on amphibole chemistry were given due to editorial limitations. Therefore, in this paper, (1) all the chemical data of the Saruta-gawa amphiboles and (2) representative analyses of minerals associated with the amphibole, which were studied in Banno (2000), are presented.

2. Sample numbers

Each sample has two sample numbers as shown in Table 1. One is the original number (e.g., YB108), which was presented in Banno (2000), and the other is registration number of the petrological collection of the Geological Museum, AIST, Tsukuba (e.g., GSJ R76512). In this paper, only the original numbers are given to simplify the description.

3. Abbreviations in the text

Abbreviations used in the text are as follows:

[1] Institute of Geoscience, GSJ

Keywords : chemical composition, amphibole, basic schist, quartz schist, Sanbagawa belt, Saruta-gawa area

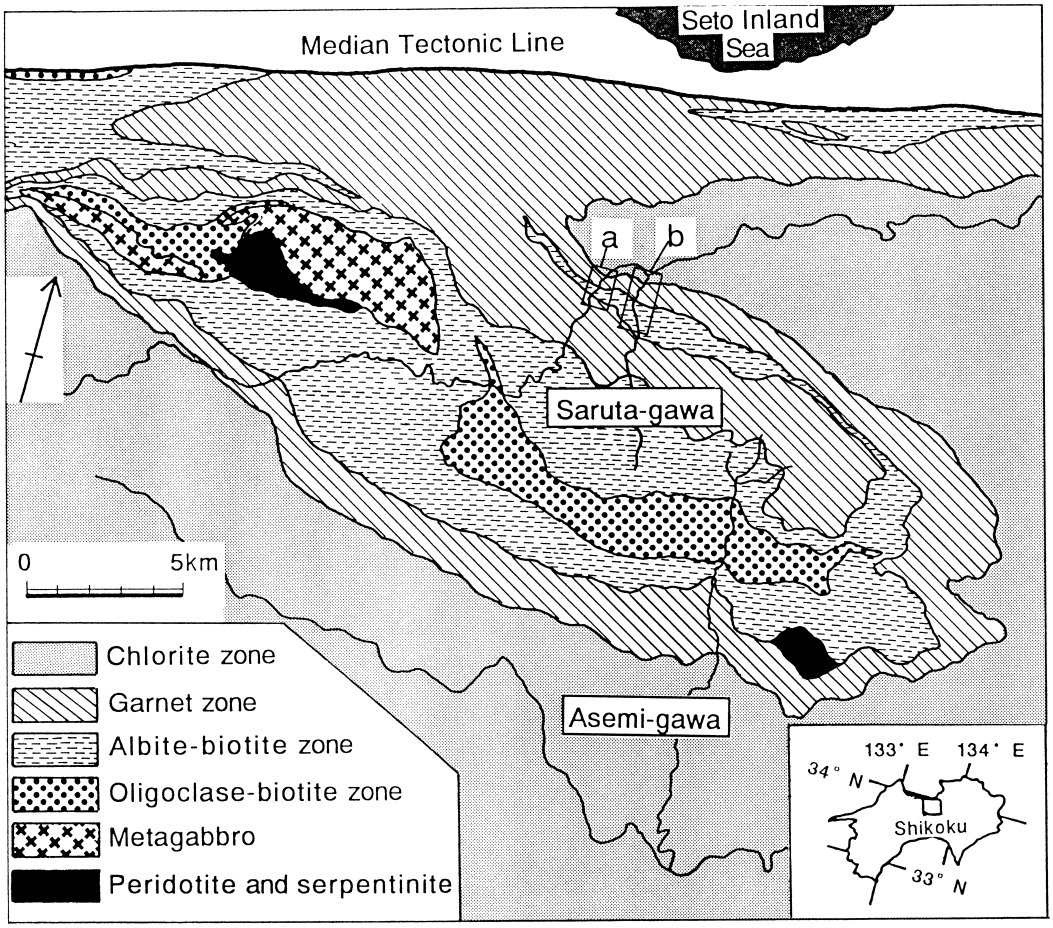

Fig. 1 Metamorphic zones in the Sanbagawa metamorphic belt, central Shikoku (simplified from Higashino, 1990). Small rectangles marked with a and b indicate the locations of traverse maps shown in Fig. 2a and b, respectively.

$^{[4]}$Al=tetrahedral aluminum, $^{[A]}$(Na+K)=sodium and potassium in A sites, $^{[B]}$Na=sodium in M4 sites, $^{[6]}$Ti=octahedral titanium.

4. Outline of geology and mineral assemblages

The Saruta-gawa area is located in Iyo-Mishima city, Ehime Prefecture in central Shikoku, and a part of the Sazare area of Higashino *et al.* (1984). Traverse maps and sample locations of the Saruta-gawa area are shown in Fig. 2. The Sanbagawa schists generally trend E–W and dip to the north. However, in the Saruta-gawa area, local southward dips caused by later folding are observed. The bed of this area strikes roughly WNW and dips about 40° to 90° south. On the basis of the mineral assemblages in pelitic schists, this area is divided into three mineral zones, the chlorite, the garnet and the albite-biotite zones in ascending order of metamorphic grade (e.g., Higashino, 1990). The analyzed samples were four basic schists and four quartz schists and were all collected from the albite-biotite zone (Fig. 2). Mineral assemblages of the samples are shown in Table 1. All the samples contain chlorite, epidote, muscovite, albite, quartz and hematite. Garnet was found exclusively in quartz schist.

5. Outline of mineral chemistry

The chemical characteristics of amphibole and other minerals listed in Tables 2 to 10 are briefly described in this chapter. Minerals in eight samples were examined by a JEOL JXA-8800R electron-probe microanalyzer at AIST. Accelerating voltage, specimen current and beam diameter were kept at 15 kV, 12 nA on a Faraday cup and 3 μm, respectively. More detailed descriptions were given in Banno (2000).

5.1 Amphibole

All the analyses of amphiboles are listed in Table 2. The Fe^{3+}/Fe^{2+} of amphibole is calculated for assuming 13 total cations exclusive of K, Na and Ca on the basis of 23 O atoms. The nomenclature of amphibole conforms to Leake *et al.* (1997). Some sodic-calcic amphiboles with $^{[4]}$Al contents higher than 0.5 per for-

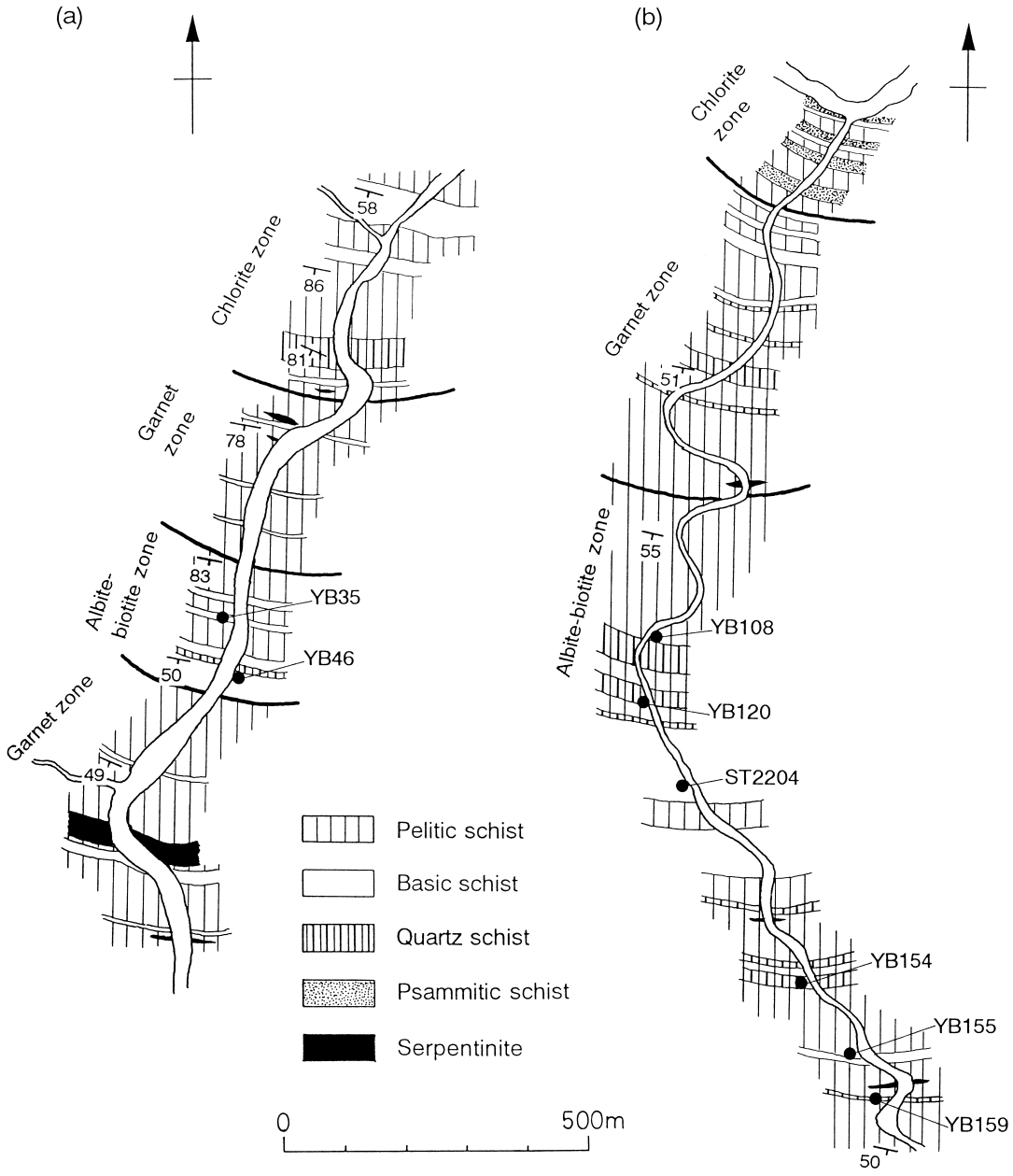

Fig. 2 Traverse maps and sample locations of the Saruta-gawa area.

mula unit (pfu) show $^{[A]}(Na+K)>0.5$ pfu, and these are magnesiokatophorites. All the sodic-calcic amphiboles containing $^{[4]}Al>0.5$ pfu are classified as barroisite in this paper to simplify the mineral description.

Amphibole occurs as matrix minerals and inclusions in the albite porphyroblasts. In this study, only matrix amphiboles were analyzed. The amphiboles possess Al-rich core and Al-poor mantle. Zoned crystals of amphiboles were examined by line scanning profiles from Al-rich core to Al-poor mantle. In Table 2, chemical data obtained from different spots in the same amphibole crystal are arranged in a sequence from core to rim. The Al-rich core has a barroisitic composition. In the mantle part, $^{[B]}Na$ increases with decreasing $^{[4]}Al$ towards margin, which has a winchite-magnesioriebeckite composition [cf. Fig. 3a and b in Banno (2000)]. The barroisite-winchite-magnesioriebeckite composite crystal is sometimes rimmed with actinolite and/or winchite with low $^{[B]}Na$ and $^{[4]}Al$. In the mantle part of this zoning pattern, $^{[B]}Na$ increases with decreasing $^{[4]}Al$, then decreases towards the margin [cf. Fig. 3c–e in Banno (2000)].

Compositional ranges of Al-rich cores and Al-poor mantles are shown on an $^{[4]}Al$-$^{[B]}Na$ diagram (Fig. 3). The barroisite core in basic schists is generally poorer in $^{[B]}Na$ than in quartz schists. The $^{[B]}Na$ content of the mantle in basic schists extends to lower values than in quartz schists. The systematic difference in $^{[B]}Na$ between basic and quartz schists can be explained by differences in oxygen fugacity between the two rock

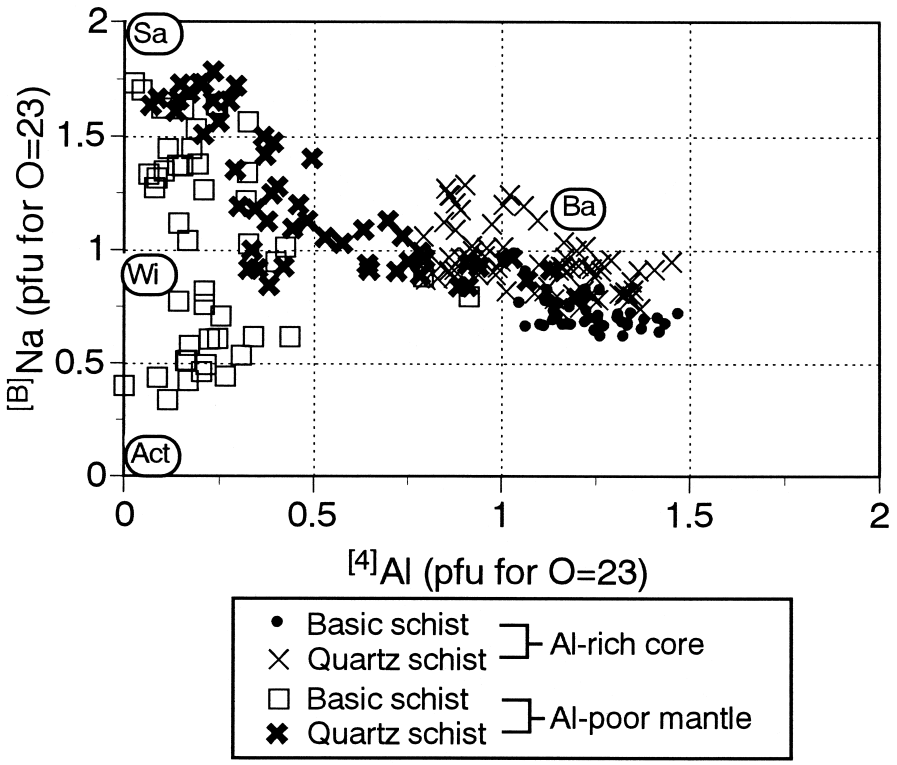

Fig. 3 Compositional ranges of Al-rich core and Al-poor mantle in basic and quartz schists from the Saruta-gawa area. Ba=barroisite, Sa=sodic amphibole, Wi=winchite, Act=actinolite.

types (Banno, 2000).

5.2 Minerals other than amphibole

Representative analyses of epidote, chlorite, garnet, muscovite, albite, hematite, magnetite and stilpnomelane are tabulated in Tables 3-10, respectively. Epidote is commonly zoned with decreasing ferrian component [$Y_{Fe^{3+}}=Fe^{3+}/(Fe^{3+}+Al)$] from core to rim (e.g., ST2204, YB35), although the zoning with reverse sense is observed in YB108. The ranges of $Y_{Fe^{3+}}$ of epidotes in basic and quartz schists are 0.21–0.31 and 0.27–0.33, respectively. Total iron was assumed to be Fe_2O_3.

Compositional ranges of X_{Sps} (=spessartine component) in garnet are generally 0.19–0.72, although garnet in YB154 shows lower X_{Sps} (0.13–0.20). Except for YB154, garnet occurs as zoned crystals in which Mn contents decrease from core ($X_{Sps}=0.55$–0.72) to rim ($X_{Sps}=0.19$–0.43). X_{Grs} (=grossular component) in garnet from YB159 increases outwards, and attains its maximum of 0.20 at an intermediate position between core and rim, and then decreases towards the outermost rim. The chemical data showing the highest X_{Grs} contents are marked with "inter" in Table 5. Mn in garnet from YB154 decreases from the core ($X_{Sps}=0.20$) towards the rim ($X_{Sps}=0.13$). The ferric iron contents of garnet were calculated on the basis of $(Al+Fe^{3+}):(Fe^{2+}+Mn+Mg+Ca)=2:3$.

Muscovite is phengitic with a Si content of 3.20–3.35 pfu (O=11). The Na/(Na+K) ratio is 0.05–0.15. Ferrous iron content was estimated as $Si+Ti-3=Fe^{2+}+Mg+Mn$ (O=11), assuming (Fe^{2+}, Mg, Mn) $SiAl_{-1}Al_{-1}$ and $^{[4]}Al^{[6]}TiSi_{-1}Al_{-1}$ substitutions.

Hematite includes fine exsolution lamellae of ilmenite. Ti contents of the host hematite are less than 0.19 pfu. In ST2204, hematite including the ilmenite lamellae is rimmed with lamellae-free hematite. The former has higher Ti contents (0.15–0.19 pfu) than the latter (0.01–0.10 pfu). Fe^{3+}/Fe^{2+} ratio was calculated assuming total cation=2 (O=3).

Magnetite occurs in YB108 and coexists with hematite. It contains small amounts of SiO_2 (0.6–0.7 wt.%). Fe^{3+}/Fe^{2+} ratio was calculated on the assumption of total cation=3 for O=4.

Stilpnomelane occurs in YB35, and is relatively rich in Mn (0.18–0.20 pfu). Formulae of stilpnomelane were calculated assuming Si=8 with total iron as Fe^{2+}.

Albite shows low Ca/(Ca+Na) (<0.02). Mg/(Mg+Fe^{2+}) values of chlorite ranges from 0.45–0.69.

Acknowledgements: The author is indebted to M. Haruna for critical reading the manuscript and to M. Enami for providing the sample ST2204. Thanks are due to H. Hirano for his improvements of the manuscript.

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Received September 28, 2001
Accepted October 30, 2001

Abbreviations used in Tables 1–10 are as follows.

(Tables 1–10) BS=basic schist, QS=quartz schist.
(Tables 2 and 4) $^{[4]}$Al=tetrahedral aluminum, $^{[6]}$Al=octahedral aluminum.
(Table 1) Grt=garnet, Amp=amphibole, Ep=epidote, Chl=chlorite, Ms=muscovite, Car=carbonate, Ttn=titanite, Rt=rutile, Ab=albite, Qtz=quartz, Hem=hematite, Ap=apatite, Mag=magnetite, Tur=tourmaline, Ilm=ilmenite, Stp=stilpnomelane.
(Table 2) Ba=barroisite, Wi=winchite, Mrb=magnesioriebeckite, Gln=glaucophane, Act=actinolite, $^{[B]}$Na=sodium in M4 sites, $^{[A]}$Na=sodium in A sites, $X_{Mg}=Mg/(Mg+Fe^{2+})$, $X_{Fe^{3+}}=Fe^{3+}/(Fe^{3+}+{}^{[6]}Al)$, *=total iron as FeO, #=the highest $^{[B]}$Na position in the mantle, n.d.=not determined.
(Table 3) $Y_{Fe^{3+}}=Fe^{3+}/(Fe^{3+}+Al)$, *=total iron as Fe_2O_3.
(Table 4) $X_{Mg}=Mg/(Mg+Fe^{2+})$.
(Table 5) inter=intermediate position, showing the highest grossular component, between core and rim, *=total iron as FeO.
(Table 6) $X_{Na}=Na/(Na+K)$, *=total iron as FeO.
(Table 7) $X_{Ca}=Ca/(Ca+Na)$.
(Table 8) *=total iron as FeO, #=lamellae-free hematite rim.
(Table 9) *=total iron as FeO.
(Table 10) $X_{Mg}=Mg/(Mg+Fe^{2+})$.

Table 1 Mineral assemblages of hematite-bearing schists in the albite-biotite zone from the Saruta-gawa area.

Sample No.															
Original No.	Registration No.	Type	Grt	Amp	Ep	Chl	Ms	Car	Ttn	Rt	Ab	Qtz	Hem	Ap	Other minerals
YB108	GSJ R76512	BS		+	+	+	+		+	+	+	+	+	+	Mag
YB120	GSJ R76513	QS	+	+	+	+	+				+	+	+	+	
ST2204	GSJ R76514	BS		+	+	+	+			+	+	+	+		
YB154	GSJ R76515	QS	+	+	+	+	+				+	+	+	+	Tur
YB155	GSJ R76516	QS	+	+	+	+	+				+	+	+	+	
YB159	GSJ R76517	QS	+	+	+	+	+				+	+	+	+	Tur
YB35	GSJ R76518	BS		+	+	+	+		+	+	+	+	+		Ilm Stp
YB46	GSJ R76519	BS		+	+	+	+	+	+		+	+	+	+	Tur

Table 2 Chemical compositions of amphibole.

Sample No.	YB108	YB108	YB108	YB108	YB108	YB108	YB108	YB108	YB108	YB108	YB108	YB108	YB108	YB108	YB108	YB108	YB120	YB120	YB120	YB120	YB120	YB120	YB120
Rock type	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	QS	QS	QS	QS	QS	QS	QS
Grain No.	2'	2'	2'	2'	2'	2'	2'	2'	3-a	3-a	3-a	3-a	3-a	3-a	3-a	3-a	b	b	b	b	b	c	c
Point No.	29	28	27	26	25	24	23	22#	39	38	37	36	35	34	33	31#	213	212	211	210	185#	209	208
	core	core	core	core	core	mantle	mantle	mantle	core	core	core	core	core	core	mantle	mantle	core	core	core	mantle	mantle	core	core
	Ba	Ba	Ba	Ba	Ba	Mrb	Mrb	Mrb	Ba	Ba	Ba	Ba	Ba	Ba	Ba	Mrb	Ba	Ba	Ba	Wi	Mrb	Ba	Ba
SiO_2	48.5	48.1	48.4	48.0	48.4	55.5	55.6	55.4	46.8	45.9	45.9	46.0	45.7	45.2	49.2	54.4	49.5	49.6	50.0	53.1	54.9	50.0	49.3
TiO_2	0.41	0.44	0.34	0.39	0.28	0.04	0.00	0.09	0.26	0.26	0.42	0.42	0.43	0.54	0.16	0.00	0.25	0.26	0.18	0.05	0.07	0.23	0.18
Al_2O_3	9.74	9.79	9.92	9.87	9.29	5.00	5.04	4.74	9.86	10.7	10.5	10.3	10.6	10.7	7.49	6.44	8.54	8.62	8.54	5.73	5.46	8.38	8.91
Cr_2O_3	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.00	0.02	0.04	0.03	0.00	0.00	0.00
FeO*	16.8	16.4	16.9	16.9	17.0	18.4	19.3	18.5	17.3	17.4	17.4	17.4	17.1	17.2	16.7	17.9	13.5	13.7	13.5	14.9	14.8	14.7	14.1
MnO	0.27	0.28	0.21	0.26	0.25	0.15	0.20	0.18	0.27	0.25	0.21	0.21	0.29	0.20	0.22	0.21	0.67	0.73	0.60	0.52	0.47	0.81	0.71
MgO	10.4	10.4	10.5	10.6	10.2	9.64	9.55	9.28	10.2	10.1	9.88	10.2	10.1	10.1	11.1	9.41	12.2	12.3	12.2	11.8	11.7	12.6	12.2
CaO	6.71	6.76	6.56	7.07	6.80	2.14	2.08	1.87	7.45	7.45	7.40	8.01	8.14	8.30	7.13	1.97	6.89	6.69	6.86	3.80	3.25	6.47	6.72
Na_2O	4.60	4.61	4.79	4.52	4.41	5.88	5.92	6.11	3.91	4.08	4.09	4.03	3.84	3.84	3.84	5.91	4.73	4.99	4.92	5.70	6.04	4.76	5.01
K_2O	0.33	0.35	0.32	0.35	0.31	0.05	0.02	0.03	0.40	0.42	0.43	0.43	0.51	0.49	0.23	0.08	0.20	0.22	0.17	0.11	0.05	0.18	0.22
Total	97.8	97.1	97.9	98.0	96.9	96.8	97.7	96.2	96.5	96.6	96.2	97.0	96.7	96.6	96.1	96.3	96.5	97.1	97.0	95.7	96.7	98.1	97.4
Fe_2O_3	7.65	7.05	8.22	7.98	7.35	9.93	11.4	9.08	8.66	9.28	8.40	7.56	7.30	7.23	8.24	10.7	6.01	6.64	5.28	8.90	7.78	10.2	7.30
FeO	9.92	10.1	9.50	9.72	10.4	9.46	9.05	10.3	9.51	9.05	9.85	10.6	10.5	10.7	9.28	8.23	8.10	7.73	8.75	6.89	7.80	5.49	7.53
New total	98.5	97.9	98.8	98.8	97.7	97.8	98.9	97.1	97.3	97.5	97.1	97.8	97.4	97.3	96.9	97.4	97.1	97.8	97.5	96.6	97.5	99.1	98.1
	Atomic ratios (O=23)																						
Si	7.000	6.992	6.967	6.927	7.054	7.902	7.849	7.957	6.873	6.740	6.777	6.765	6.742	6.690	7.199	7.757	7.166	7.134	7.205	7.635	7.791	7.080	7.080
$^{[4]}Al$	1.000	1.008	1.033	1.073	0.946	0.098	0.151	0.043	1.127	1.260	1.223	1.235	1.258	1.310	0.801	0.243	0.834	0.866	0.795	0.365	0.209	0.920	0.920
$^{[6]}Al$	0.657	0.670	0.650	0.606	0.650	0.741	0.688	0.759	0.580	0.592	0.604	0.551	0.585	0.557	0.490	0.840	0.623	0.595	0.655	0.607	0.704	0.478	0.589
Ti	0.045	0.048	0.037	0.042	0.031	0.004	0.000	0.010	0.029	0.029	0.047	0.046	0.048	0.060	0.018	0.000	0.027	0.028	0.020	0.005	0.007	0.024	0.019
Cr																	0.000	0.002	0.005	0.003	0.000	0.000	0.000
Fe^{3+}	0.831	0.772	0.890	0.867	0.807	1.064	1.210	0.982	0.957	1.025	0.933	0.837	0.810	0.805	0.908	1.153	0.654	0.718	0.573	0.964	0.830	1.091	0.789
Fe^{2+}	1.197	1.222	1.144	1.173	1.265	1.127	1.069	1.240	1.168	1.112	1.216	1.304	1.300	1.324	1.136	0.982	0.980	0.930	1.054	0.828	0.926	0.650	0.905
Mn	0.033	0.034	0.026	0.032	0.031	0.018	0.024	0.022	0.034	0.031	0.026	0.026	0.036	0.025	0.027	0.025	0.082	0.089	0.073	0.063	0.056	0.097	0.086
Mg	2.238	2.254	2.253	2.280	2.216	2.046	2.010	1.987	2.233	2.211	2.175	2.236	2.221	2.229	2.421	2.000	2.633	2.637	2.621	2.530	2.475	2.660	2.612
Ca	1.038	1.053	1.012	1.093	1.062	0.326	0.315	0.288	1.172	1.172	1.171	1.262	1.287	1.316	1.118	0.301	1.069	1.031	1.059	0.585	0.494	0.982	1.034
Na	1.287	1.299	1.337	1.265	1.246	1.623	1.620	1.702	1.113	1.162	1.171	1.149	1.098	1.102	1.089	1.634	1.328	1.392	1.375	1.589	1.662	1.307	1.395
K	0.061	0.065	0.059	0.064	0.058	0.009	0.004	0.005	0.075	0.079	0.081	0.081	0.096	0.093	0.043	0.015	0.037	0.040	0.031	0.020	0.009	0.033	0.040
Total	15.386	15.417	15.407	15.422	15.366	14.959	14.939	14.995	15.361	15.413	15.422	15.492	15.481	15.511	15.250	14.950	15.433	15.463	15.465	15.195	15.165	15.321	15.469
$^{[B]}Na$	0.962	0.947	0.988	0.907	0.938	1.623	1.620	1.702	0.828	0.828	0.829	0.738	0.713	0.684	0.882	1.634	0.931	0.969	0.941	1.415	1.506	1.018	0.966
$^{[A]}Na$	0.325	0.352	0.349	0.358	0.308	0.000	0.000	0.000	0.286	0.334	0.341	0.411	0.385	0.418	0.207	0.000	0.396	0.423	0.434	0.175	0.156	0.288	0.429
XMg	0.651	0.648	0.663	0.660	0.637	0.645	0.653	0.616	0.657	0.665	0.641	0.632	0.631	0.627	0.681	0.671	0.729	0.739	0.713	0.753	0.728	0.804	0.743
XFe^{3+}	0.558	0.535	0.578	0.589	0.554	0.590	0.638	0.564	0.623	0.634	0.607	0.603	0.581	0.591	0.649	0.579	0.512	0.547	0.466	0.614	0.541	0.695	0.573

Table 2 Chemical compositions of amphibole (continued).

Sample No.	YB120	YB120	YB120	YB120	YB120	YB120	YB120	YB120	YB120	YB120	YB120	YB120	YB120	YB120	YB120	YB120	YB120	YB120	YB120	YB120	YB120	YB120	YB120
Rock type	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS
Grain No.	c	c	c	c	d	d	d	d	d	d	d	e	e	e	e	e	e	e	e	e	e	e	e
Point No.	207	217	218	219#	231	230	188	226	227	228	229#	255	254	253	252	251	250	249	248	247	246	245	244
	core	mantle	mantle	mantle	core	core	core	mantle	mantle	mantle	mantle	core	core	core	core	core	core	core	core	core	core	core	core
	Ba	Mrb	Wi	Mrb	Ba	Ba	Ba	Wi	Mrb	Mrb	Mrb	Ba	Ba	Ba	Ba	Ba	Ba	Ba	Ba	Ba	Ba	Ba	Ba
SiO_2	49.9	55.5	54.0	55.2	49.2	49.2	49.6	53.9	55.8	55.8	56.7	50.1	50.3	50.4	49.2	49.5	48.9	49.0	49.5	49.3	49.7	49.3	49.5
TiO_2	0.18	0.03	0.05	0.04	0.24	0.21	0.23	0.08	0.00	0.07	0.03	0.15	0.20	0.33	0.20	0.20	0.12	0.21	0.16	0.17	0.10	0.15	0.22
Al_2O_3	8.36	5.19	5.35	4.92	9.33	9.23	9.30	6.54	5.75	5.39	5.39	9.58	9.89	9.84	10.0	9.84	10.1	9.55	9.10	8.99	8.26	8.54	8.50
Cr_2O_3	0.00	0.00	0.00	0.06	0.01	0.04	0.00	0.00	0.00	0.05	0.01	0.03	0.01	0.00	0.03	0.05	0.00	0.03	0.00	0.00	0.03	0.00	0.00
FeO*	13.9	15.5	16.2	16.4	13.8	13.4	13.9	14.7	14.1	14.1	14.9	13.9	14.2	13.8	14.1	13.9	13.4	13.9	13.6	14.5	14.4	13.6	13.7
MnO	0.69	0.39	0.54	0.36	0.59	0.74	0.64	0.47	0.55	0.53	0.49	0.78	0.96	0.71	0.78	0.56	0.66	0.69	0.66	0.59	0.69	0.66	0.66
MgO	12.9	12.1	11.8	11.4	12.6	12.4	12.8	11.9	11.7	11.9	11.4	11.7	11.7	11.6	11.7	11.4	11.8	12.3	12.6	12.3	12.4	12.4	12.5
CaO	6.78	2.30	3.32	1.79	7.26	7.21	7.12	3.49	2.27	2.60	2.46	4.98	4.72	4.82	5.80	5.92	6.43	6.85	6.91	6.71	7.09	7.02	7.28
Na_2O	5.09	6.34	6.02	6.45	4.89	4.90	4.32	6.22	6.43	6.17	6.20	5.82	6.11	6.04	5.42	5.00	5.19	4.67	4.77	4.98	4.90	4.47	4.54
K_2O	0.23	0.07	0.07	0.02	0.19	0.22	0.23	0.11	0.05	0.04	0.05	0.20	0.16	0.17	0.23	0.21	0.24	0.18	0.20	0.19	0.22	0.19	0.18
Total	98.0	97.4	97.4	96.6	98.1	97.6	98.1	97.4	96.7	96.7	97.6	97.2	98.3	97.7	97.5	96.6	96.8	97.4	97.5	97.7	97.8	96.3	97.1
Fe_2O_3	7.83	11.4	10.9	12.0	7.01	5.99	9.41	8.49	8.23	8.24	7.77	8.56	9.55	7.84	8.43	7.26	6.40	8.53	7.73	8.31	6.87	7.25	6.64
FeO	6.86	5.26	6.41	5.63	7.49	8.01	5.44	7.06	6.70	6.68	7.91	6.20	5.61	6.75	6.52	7.37	7.64	6.23	6.64	7.03	8.21	7.07	7.73
New total	98.8	98.6	98.5	97.9	98.8	98.2	99.1	98.3	97.5	97.5	98.4	98.1	99.2	98.5	98.3	97.3	97.5	98.2	98.3	98.6	98.5	97.1	97.8
	Atomic ratios (O=23)																						
Si	7.103	7.760	7.635	7.792	7.012	7.061	7.010	7.608	7.861	7.865	7.930	7.137	7.089	7.147	7.024	7.120	7.044	7.001	7.067	7.044	7.128	7.129	7.124
$^{[4]}Al$	0.897	0.240	0.365	0.208	0.988	0.939	0.990	0.392	0.139	0.135	0.070	0.863	0.911	0.853	0.976	0.880	0.956	0.999	0.933	0.956	0.872	0.871	0.876
$^{[6]}Al$	0.505	0.616	0.527	0.611	0.580	0.622	0.559	0.696	0.816	0.761	0.818	0.746	0.731	0.791	0.707	0.788	0.758	0.610	0.598	0.558	0.524	0.585	0.565
Ti	0.019	0.003	0.005	0.004	0.026	0.023	0.024	0.008	0.000	0.007	0.003	0.016	0.021	0.035	0.021	0.022	0.013	0.023	0.017	0.018	0.011	0.016	0.024
Cr	0.000	0.000	0.000	0.007	0.001	0.005	0.000	0.000	0.000	0.006	0.001	0.003	0.001	0.000	0.003	0.006	0.000	0.003	0.000	0.000	0.003	0.000	0.000
Fe^{3+}	0.839	1.197	1.158	1.271	0.752	0.647	1.000	0.901	0.872	0.874	0.817	0.918	1.013	0.836	0.906	0.786	0.694	0.917	0.831	0.893	0.742	0.789	0.719
Fe^{2+}	0.816	0.616	0.758	0.665	0.893	0.961	0.643	0.834	0.789	0.788	0.925	0.738	0.661	0.800	0.778	0.886	0.921	0.744	0.793	0.840	0.985	0.855	0.930
Mn	0.083	0.046	0.065	0.043	0.071	0.090	0.077	0.056	0.066	0.063	0.058	0.094	0.115	0.085	0.094	0.068	0.081	0.084	0.080	0.071	0.084	0.081	0.080
Mg	2.737	2.522	2.487	2.399	2.677	2.653	2.697	2.504	2.457	2.501	2.377	2.485	2.458	2.452	2.490	2.444	2.534	2.620	2.682	2.620	2.651	2.673	2.682
Ca	1.034	0.345	0.503	0.271	1.109	1.109	1.078	0.528	0.343	0.393	0.369	0.760	0.713	0.732	0.887	0.912	0.992	1.049	1.057	1.027	1.089	1.088	1.122
Na	1.405	1.719	1.650	1.765	1.351	1.363	1.184	1.702	1.756	1.686	1.681	1.608	1.670	1.661	1.500	1.394	1.450	1.294	1.320	1.380	1.363	1.253	1.267
K	0.042	0.012	0.013	0.004	0.035	0.040	0.041	0.020	0.009	0.007	0.009	0.036	0.029	0.031	0.042	0.039	0.044	0.033	0.036	0.035	0.040	0.035	0.033
Total	15.481	15.076	15.166	15.040	15.495	15.512	15.303	15.250	15.108	15.086	15.059	15.404	15.411	15.424	15.429	15.345	15.486	15.375	15.414	15.441	15.492	15.376	15.422
$^{[B]}Na$	0.966	1.655	1.497	1.729	0.891	0.891	0.922	1.472	1.657	1.607	1.631	1.240	1.287	1.268	1.113	1.088	1.008	0.951	0.943	0.973	0.911	0.912	0.878
$^{[A]}Na$	0.439	0.063	0.153	0.036	0.460	0.472	0.262	0.230	0.099	0.079	0.050	0.368	0.382	0.393	0.388	0.307	0.442	0.342	0.377	0.407	0.452	0.341	0.389
XMg	0.770	0.804	0.767	0.783	0.750	0.734	0.808	0.750	0.757	0.760	0.720	0.771	0.788	0.754	0.762	0.734	0.734	0.779	0.772	0.757	0.729	0.758	0.743
XFe^{3+}	0.624	0.660	0.687	0.675	0.565	0.510	0.641	0.564	0.517	0.535	0.500	0.552	0.581	0.514	0.562	0.499	0.478	0.601	0.582	0.616	0.586	0.574	0.560

Table 2 Chemical compositions of amphibole (continued).

Sample No.	YB120	YB120	YB120	YB120	YB120	YB120	YB120	YB120	YB120	YB120	YB120	YB120	ST2204	ST2204	ST2204	ST2204	ST2204	ST2204	ST2204	ST2204	ST2204	ST2204	ST2204
Rock type	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS
Grain No.	e	e	e	e	e	e	e	e	e	e	e	e	3	3	3	3	3	3	3	3	3	3	3
Point No.	243	242	241	240	239	238	237	236	235	234	233	232#	37	36	35	34	33	32	31	30	29#	28	27
	mantle	mantle	mantle	mantle	mantle	mantle	mantle	mantle	mantle	mantle	mantle	mantle	core	core	core	core	core	core	mantle	mantle	mantle	mantle	mantle
	Ba	Ba	Wi	Wi	Mrb	Mrb	Mrb	Gln	Mrb	Mrb	Mrb	Mrb	Ba	Ba	Ba	Ba	Ba	Ba	Wi	Wi	Mrb	Wi	Wi
SiO_2	50.3	51.1	52.4	53.5	54.9	55.2	55.6	55.3	56.2	56.6	55.8	54.7	44.4	44.6	45.7	44.5	44.9	45.1	53.6	53.8	54.4	53.2	54.0
TiO_2	0.18	0.07	0.20	0.09	0.03	0.02	0.08	0.08	0.00	0.09	0.05	0.05	0.47	0.48	0.43	0.63	0.43	0.36	0.02	0.15	0.13	0.07	0.10
Al_2O_3	7.58	6.82	6.45	6.18	6.06	6.32	6.36	5.82	5.73	5.41	5.25	5.33	11.5	11.4	10.7	11.6	11.3	10.9	2.91	3.85	4.45	2.40	1.74
Cr_2O_3	0.03	0.00	0.02	0.00	0.02	0.00	0.04	0.06	0.00	0.04	0.01	0.00	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
FeO*	14.2	14.3	14.0	15.2	14.4	15.1	15.1	13.6	15.4	15.5	16.1	16.0	16.9	17.0	17.2	17.4	16.9	16.3	16.7	17.7	19.1	14.9	14.6
MnO	0.51	0.67	0.55	0.61	0.62	0.42	0.45	0.44	0.36	0.40	0.61	0.39	0.25	0.16	0.15	0.27	0.26	0.24	0.30	0.16	0.14	0.33	0.27
MgO	12.5	12.4	12.1	12.4	11.7	11.7	11.6	11.3	11.3	11.8	11.4	11.3	10.2	10.3	10.8	10.2	10.6	10.7	13.7	11.8	10.3	14.4	14.6
CaO	6.82	5.90	5.20	3.98	2.90	1.86	2.33	2.19	1.77	2.08	1.81	1.43	8.36	8.60	8.17	8.14	8.26	8.40	6.93	4.32	2.36	8.95	9.05
Na_2O	4.90	4.44	5.32	6.01	6.44	6.58	6.43	6.39	6.36	6.62	6.91	6.91	4.21	4.07	4.20	4.36	3.84	4.13	3.53	4.97	6.24	2.23	2.21
K_2O	0.16	0.19	0.17	0.11	0.07	0.04	0.07	0.07	0.05	0.04	0.01	0.02	0.62	0.59	0.44	0.60	0.54	0.51	0.04	0.07	0.03	0.09	0.07
Total	97.2	95.9	96.4	98.1	97.1	97.2	98.1	95.3	97.2	98.6	98.0	96.1	96.9	97.2	97.8	97.7	97.0	96.6	97.7	96.8	97.2	96.6	96.6
Fe_2O_3	6.42	9.22	6.18	10.2	7.82	11.4	9.88	6.62	10.2	9.94	10.5	11.5	6.96	6.80	8.55	8.07	9.11	6.84	11.5	11.5	11.8	7.91	6.65
FeO	8.42	6.01	8.43	6.03	7.36	4.89	6.21	7.64	6.18	6.56	6.62	5.67	10.6	10.9	9.51	10.1	8.70	10.1	6.35	7.39	8.51	7.78	8.62
New total	97.8	96.8	97.0	99.1	97.9	98.4	99.1	95.9	98.2	99.6	99.0	97.3	97.6	97.9	98.7	98.5	97.9	97.3	98.9	98.0	98.4	97.4	97.3
	Atomic ratios (O=23)																						
Si	7.239	7.364	7.537	7.514	7.750	7.709	7.731	7.912	7.857	7.830	7.799	7.765	6.570	6.581	6.657	6.527	6.581	6.662	7.600	7.687	7.755	7.660	7.771
$^{[4]}Al$	0.761	0.636	0.463	0.486	0.250	0.291	0.269	0.088	0.143	0.170	0.201	0.235	1.430	1.419	1.343	1.473	1.419	1.338	0.400	0.313	0.245	0.340	0.229
$^{[6]}Al$	0.524	0.523	0.630	0.537	0.758	0.749	0.774	0.894	0.802	0.712	0.664	0.657	0.575	0.563	0.494	0.532	0.533	0.560	0.086	0.336	0.503	0.067	0.067
Ti	0.019	0.008	0.022	0.010	0.003	0.002	0.008	0.009	0.000	0.009	0.005	0.005	0.052	0.053	0.047	0.069	0.047	0.040	0.002	0.016	0.014	0.008	0.011
Cr	0.003	0.000	0.002	0.000	0.002	0.000	0.004	0.007	0.000	0.004	0.001	0.000											
Fe^{3+}	0.695	1.000	0.669	1.077	0.831	1.193	1.034	0.713	1.078	1.035	1.109	1.227	0.775	0.755	0.937	0.891	1.005	0.760	1.227	1.232	1.263	0.857	0.720
Fe^{2+}	1.014	0.724	1.015	0.708	0.869	0.571	0.722	0.914	0.723	0.759	0.773	0.673	1.316	1.343	1.158	1.243	1.066	1.254	0.753	0.883	1.014	0.937	1.037
Mn	0.062	0.082	0.067	0.073	0.074	0.050	0.053	0.053	0.043	0.047	0.072	0.047	0.031	0.020	0.019	0.034	0.032	0.030	0.036	0.019	0.017	0.040	0.033
Mg	2.682	2.664	2.595	2.596	2.462	2.436	2.405	2.410	2.355	2.434	2.375	2.391	2.250	2.266	2.345	2.230	2.316	2.356	2.896	2.514	2.189	3.091	3.132
Ca	1.052	0.911	0.801	0.599	0.439	0.278	0.347	0.336	0.265	0.308	0.271	0.218	1.325	1.360	1.275	1.279	1.297	1.329	1.053	0.661	0.360	1.381	1.395
Na	1.367	1.241	1.484	1.637	1.763	1.782	1.734	1.773	1.724	1.776	1.873	1.902	1.208	1.164	1.186	1.240	1.091	1.183	0.970	1.377	1.725	0.623	0.617
K	0.029	0.035	0.031	0.020	0.013	0.007	0.012	0.013	0.009	0.007	0.002	0.004	0.117	0.111	0.082	0.112	0.101	0.096	0.007	0.013	0.005	0.017	0.013
Total	15.448	15.187	15.316	15.255	15.214	15.067	15.093	15.121	14.998	15.091	15.145	15.123	15.650	15.635	15.543	15.631	15.489	15.609	15.030	15.051	15.091	15.020	15.025
$^{[B]}Na$	0.948	1.089	1.199	1.401	1.561	1.722	1.653	1.664	1.724	1.692	1.729	1.782	0.675	0.640	0.725	0.721	0.703	0.671	0.947	1.339	1.640	0.619	0.605
$^{[A]}Na$	0.419	0.152	0.285	0.235	0.201	0.060	0.081	0.108	0.000	0.084	0.144	0.119	0.533	0.524	0.461	0.519	0.388	0.512	0.023	0.038	0.085	0.003	0.012
XMg	0.726	0.786	0.719	0.786	0.739	0.810	0.769	0.725	0.765	0.762	0.754	0.780	0.631	0.628	0.669	0.642	0.685	0.653	0.794	0.740	0.683	0.767	0.751
XFe^{3+}	0.570	0.657	0.515	0.667	0.523	0.614	0.572	0.444	0.574	0.592	0.625	0.651	0.574	0.573	0.655	0.626	0.654	0.576	0.935	0.786	0.715	0.927	0.915

Table 2 Chemical compositions of amphibole (continued).

Sample No.	YB154	YB154	YB154	YB154	YB154	YB154	YB154	YB154	YB154	YB154	YB154	YB154	YB154	YB154	YB154	YB154	YB154	YB154	YB154	YB154	YB154	YB154	YB154
Rock type	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS
Grain No.	11b	11b	11b	11b	11b	11b	11b	11b	11b	11b	11b	11b	11b	11b	11b	11b	11b	11b	11b	11b	11b	18	18
Point No.	88	89	90	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107#	108	109	131	132
	core	core	core	core	core	core	core	core	core	core	core	core	mantle	mantle	mantle	mantle	mantle	mantle	mantle	mantle	mantle	core	core
	Ba	Ba	Ba	Ba	Ba	Ba	Ba	Ba	Ba	Ba	Ba	Ba	Ba	Ba	Ba	Ba	Ba	Wi	Wi	Wi	Wi	Ba	Ba
SiO_2	44.5	45.3	44.9	45.2	45.2	45.0	45.7	46.9	45.6	45.6	45.9	46.1	46.8	46.7	48.0	50.0	50.3	52.6	53.6	53.1	52.8	45.4	45.3
TiO_2	0.26	0.28	0.32	0.33	0.34	0.38	0.22	0.26	0.32	0.30	0.34	0.22	0.23	0.29	0.26	0.17	0.17	0.09	0.08	0.06	0.06	0.28	0.34
Al_2O_3	11.8	12.2	12.3	11.8	12.2	11.9	11.1	9.63	11.6	11.1	10.9	10.9	10.5	9.45	8.96	7.57	7.30	5.11	4.03	3.75	3.06	11.5	11.9
Cr_2O_3	0.02	0.04	0.02	0.02	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.02	0.01	0.01	0.00	0.02	0.00	0.00	0.01	0.04
FeO*	17.6	17.4	17.4	17.3	15.8	16.8	17.2	18.5	17.2	16.6	17.6	16.9	17.2	17.1	17.1	17.5	17.9	19.5	20.3	20.7	19.1	17.8	16.6
MnO	0.41	0.46	0.40	0.40	0.35	0.24	0.38	0.39	0.26	0.41	0.27	0.34	0.37	0.44	0.35	0.43	0.44	0.39	0.28	0.39	0.66	0.36	0.46
MgO	9.46	9.38	9.80	9.54	8.96	9.53	9.48	9.60	9.80	9.38	9.72	9.93	10.3	10.0	10.1	10.4	10.2	9.87	9.88	10.1	11.5	9.47	9.81
CaO	6.85	6.96	6.73	7.23	7.35	7.68	7.54	7.50	7.59	7.46	7.75	7.95	7.78	7.14	6.83	6.03	5.61	4.66	4.21	5.31	7.48	7.52	7.49
Na_2O	4.73	5.24	4.95	4.76	4.82	4.51	4.87	4.47	4.19	4.26	4.45	4.40	4.41	4.33	4.68	4.78	5.19	5.21	5.32	4.77	3.44	4.63	4.23
K_2O	0.38	0.37	0.35	0.33	0.40	0.44	0.39	0.33	0.36	0.33	0.34	0.36	0.34	0.21	0.24	0.20	0.18	0.13	0.08	0.10	0.10	0.34	0.40
Total	96.0	97.6	97.2	96.9	95.5	96.5	96.9	97.6	96.9	95.4	97.3	97.1	97.9	95.7	96.5	97.1	97.3	97.6	97.8	98.3	98.2	97.3	96.6
Fe_2O_3	9.85	7.59	10.5	8.02	3.33	6.23	5.51	7.37	8.37	6.16	6.96	5.98	7.39	7.83	6.72	8.18	8.03	9.19	9.97	9.84	8.69	7.73	8.29
FeO	8.74	10.6	7.95	10.1	12.8	11.2	12.2	11.9	9.66	11.1	11.3	11.5	10.5	10.1	11.1	10.1	10.7	11.2	11.3	11.8	11.3	10.8	9.14
New total	97.0	98.4	98.2	97.7	95.8	97.1	97.4	98.4	97.8	96.1	97.9	97.7	98.6	96.5	97.3	97.9	98.1	98.5	98.8	99.2	99.1	98.0	97.4
	Atomic ratios (O=23)																						
Si	6.590	6.628	6.547	6.647	6.775	6.663	6.768	6.885	6.681	6.804	6.747	6.784	6.805	6.927	7.057	7.258	7.299	7.594	7.711	7.648	7.616	6.670	6.654
$^{[4]}Al$	1.410	1.372	1.453	1.353	1.225	1.337	1.232	1.115	1.319	1.196	1.253	1.216	1.195	1.073	0.943	0.742	0.701	0.406	0.289	0.352	0.384	1.330	1.346
$^{[6]}Al$	0.649	0.732	0.661	0.692	0.931	0.740	0.705	0.551	0.684	0.756	0.635	0.674	0.605	0.580	0.609	0.553	0.547	0.464	0.394	0.284	0.136	0.662	0.713
Ti	0.029	0.031	0.035	0.036	0.038	0.042	0.024	0.029	0.035	0.034	0.038	0.024	0.025	0.032	0.029	0.019	0.019	0.010	0.009	0.006	0.007	0.031	0.038
Cr	0.002	0.005	0.002	0.002	0.004	0.004	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.002	0.001	0.001	0.000	0.002	0.000	0.000	0.001	0.005
Fe^{3+}	1.097	0.835	1.152	0.888	0.375	0.694	0.614	0.814	0.923	0.691	0.770	0.663	0.809	0.874	0.743	0.894	0.877	0.998	1.080	1.066	0.943	0.855	0.916
Fe^{2+}	1.082	1.294	0.970	1.240	1.605	1.387	1.516	1.457	1.184	1.380	1.394	1.417	1.283	1.248	1.359	1.231	1.295	1.356	1.363	1.427	1.361	1.333	1.123
Mn	0.051	0.057	0.049	0.050	0.044	0.030	0.048	0.048	0.032	0.052	0.034	0.042	0.046	0.055	0.044	0.053	0.054	0.048	0.034	0.048	0.081	0.045	0.057
Mg	2.088	2.046	2.130	2.091	2.002	2.104	2.093	2.101	2.141	2.087	2.130	2.178	2.233	2.211	2.214	2.250	2.207	2.124	2.119	2.169	2.473	2.074	2.148
Ca	1.087	1.091	1.051	1.139	1.180	1.218	1.196	1.180	1.192	1.193	1.221	1.253	1.212	1.135	1.076	0.938	0.872	0.721	0.649	0.819	1.156	1.184	1.179
Na	1.358	1.487	1.399	1.357	1.401	1.295	1.398	1.272	1.190	1.232	1.268	1.255	1.243	1.245	1.334	1.345	1.460	1.458	1.484	1.332	0.962	1.319	1.205
K	0.072	0.069	0.065	0.062	0.076	0.083	0.074	0.062	0.067	0.063	0.064	0.068	0.063	0.040	0.045	0.037	0.033	0.024	0.015	0.018	0.018	0.064	0.075
Total	15.517	15.647	15.516	15.558	15.658	15.596	15.668	15.514	15.449	15.488	15.553	15.576	15.519	15.420	15.455	15.320	15.366	15.203	15.147	15.170	15.136	15.566	15.458
$^{[B]}Na$	0.913	0.909	0.949	0.861	0.820	0.782	0.804	0.820	0.808	0.807	0.779	0.747	0.788	0.865	0.924	1.062	1.128	1.279	1.351	1.181	0.844	0.816	0.821
$^{[A]}Na$	0.445	0.578	0.451	0.496	0.581	0.513	0.595	0.452	0.382	0.425	0.489	0.509	0.455	0.380	0.410	0.283	0.332	0.179	0.133	0.151	0.118	0.503	0.383
XMg	0.659	0.613	0.687	0.628	0.555	0.603	0.580	0.590	0.644	0.602	0.604	0.606	0.635	0.639	0.620	0.646	0.630	0.610	0.609	0.603	0.645	0.609	0.657
XFe^{3+}	0.628	0.533	0.635	0.562	0.287	0.484	0.466	0.596	0.574	0.478	0.548	0.496	0.572	0.601	0.550	0.618	0.616	0.683	0.733	0.790	0.874	0.564	0.562

Table 2 Chemical compositions of amphibole (continued).

Sample No.	YB154	YB154	YB154	YB154	YB154	YB154	YB154	YB154	YB154	YB154	YB154	YB154	YB154	YB155	YB155	YB155	YB155	YB155	YB155	YB155	YB155	YB155	YB155
Rock type	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS
Grain No.	18	18	18	18	18	18	18	18	18	18	18	18	18	27	27	27	27	27	27	27	27	27	27
Point No.	133	134	135	136	137	138	139	140	141	142	143	144	145#	39	41	42	43	44	45	46	47	49	50
	core	core	core	core	core	core	core	core	core	mantle	mantle	mantle	mantle	core	core	core	core	core	core	core	core	core	core
	Ba	Ba	Ba	Ba	Ba	Ba	Ba	Ba	Ba	Ba	Ba	Wi	Wi	Ba	Ba	Ba	Ba	Ba	Ba	Ba	Ba	Ba	Ba
SiO_2	44.6	45.2	45.8	45.6	45.8	46.6	46.7	46.9	46.8	48.1	47.4	52.8	53.1	47.1	47.3	47.8	47.9	47.8	48.6	46.6	46.5	47.1	47.1
TiO_2	0.31	0.39	0.29	0.30	0.26	0.31	0.25	0.31	0.23	0.24	0.24	0.00	0.02	0.26	0.36	0.17	0.20	0.22	0.29	0.28	0.25	0.21	0.18
Al_2O_3	11.4	11.1	11.5	11.5	11.1	10.8	10.5	10.2	9.99	9.06	9.71	4.82	4.70	10.7	10.4	10.6	10.5	10.5	8.82	10.5	10.9	10.4	10.9
Cr_2O_3	0.00	0.00	0.01	0.00	0.00	0.04	0.01	0.01	0.00	0.04	0.01	0.01	0.01	0.00	0.07	0.00	0.00	0.02	0.00	0.00	0.00	0.05	0.03
FeO*	17.0	17.3	17.4	17.4	16.2	17.0	16.7	16.1	16.9	17.3	17.1	17.1	17.4	11.8	11.2	11.6	11.5	11.5	13.2	11.3	11.1	12.1	11.8
MnO	0.41	0.49	0.35	0.34	0.33	0.41	0.30	0.43	0.40	0.44	0.37	0.38	0.22	1.00	1.07	1.11	1.02	1.02	1.01	1.14	1.00	1.16	1.13
MgO	9.84	9.98	9.86	9.87	9.38	10.3	10.1	9.61	9.98	10.7	8.97	11.3	10.9	13.6	13.2	13.3	13.6	13.5	12.9	13.4	13.3	13.9	13.4
CaO	7.91	7.62	7.67	7.62	7.84	7.78	7.73	7.42	7.54	6.67	7.25	5.66	5.21	6.93	6.93	7.02	7.19	6.75	6.41	6.97	7.15	6.84	7.13
Na_2O	4.50	4.60	4.63	4.73	4.56	4.55	4.43	4.39	4.61	4.69	4.59	4.57	4.71	4.56	4.54	4.58	4.72	4.71	4.84	4.73	4.82	4.38	4.73
K_2O	0.40	0.35	0.36	0.35	0.36	0.28	0.25	0.28	0.27	0.24	0.27	0.12	0.08	0.35	0.36	0.39	0.37	0.33	0.34	0.36	0.31	0.34	0.38
Total	96.4	97.0	97.9	97.7	95.8	98.1	97.0	95.7	96.7	97.5	95.9	96.8	96.4	96.3	95.4	96.6	97.0	96.4	96.4	95.3	95.3	96.5	96.8
Fe_2O_3	7.09	8.16	7.51	7.53	3.32	7.22	6.11	4.35	5.81	9.52	3.30	7.93	7.64	11.3	8.83	9.38	9.00	10.1	9.83	9.63	8.50	13.5	10.1
FeO	10.6	9.96	10.6	10.6	13.2	10.5	11.2	12.2	11.7	8.73	14.1	9.97	10.5	1.64	3.26	3.16	3.40	2.41	4.35	2.63	3.45	0.00	2.73
New total	97.1	97.9	98.6	98.4	96.2	98.8	97.6	96.1	97.3	98.4	96.2	97.6	97.1	97.4	96.3	97.5	97.9	97.4	97.4	96.2	96.2	97.9	97.8
	Atomic ratios (O=23)																						
Si	6.626	6.652	6.680	6.666	6.852	6.768	6.856	6.983	6.906	6.965	7.081	7.630	7.700	6.736	6.845	6.837	6.829	6.831	6.994	6.763	6.755	6.702	6.735
$^{[4]}Al$	1.374	1.348	1.320	1.334	1.148	1.232	1.144	1.017	1.094	1.035	0.919	0.370	0.300	1.264	1.155	1.163	1.171	1.169	1.006	1.237	1.245	1.298	1.265
$^{[6]}Al$	0.622	0.577	0.657	0.647	0.810	0.616	0.673	0.772	0.643	0.511	0.791	0.451	0.503	0.540	0.619	0.624	0.594	0.600	0.490	0.559	0.621	0.446	0.572
Ti	0.035	0.043	0.032	0.033	0.029	0.034	0.028	0.035	0.026	0.026	0.027	0.000	0.002	0.028	0.039	0.018	0.021	0.024	0.031	0.031	0.027	0.022	0.019
Cr	0.000	0.000	0.001	0.000	0.000	0.005	0.001	0.001	0.000	0.005	0.001	0.001	0.001	0.000	0.008	0.000	0.000	0.002	0.000	0.000	0.000	0.006	0.003
Fe^{3+}	0.792	0.904	0.824	0.829	0.374	0.789	0.675	0.487	0.646	1.037	0.371	0.862	0.833	1.216	0.961	1.010	0.966	1.087	1.065	1.052	0.929	1.440	1.084
Fe^{2+}	1.320	1.226	1.299	1.298	1.653	1.275	1.376	1.518	1.440	1.058	1.766	1.205	1.277	0.196	0.394	0.378	0.406	0.288	0.524	0.319	0.420	0.000	0.327
Mn	0.052	0.061	0.043	0.042	0.042	0.050	0.037	0.054	0.050	0.054	0.047	0.047	0.027	0.121	0.131	0.134	0.123	0.123	0.123	0.140	0.123	0.140	0.137
Mg	2.179	2.190	2.144	2.151	2.092	2.230	2.211	2.133	2.195	2.310	1.998	2.434	2.356	2.900	2.848	2.836	2.891	2.876	2.767	2.899	2.880	2.949	2.857
Ca	1.259	1.201	1.199	1.193	1.257	1.211	1.216	1.184	1.192	1.035	1.160	0.876	0.809	1.062	1.074	1.076	1.098	1.034	0.988	1.084	1.113	1.043	1.092
Na	1.296	1.313	1.309	1.341	1.323	1.281	1.261	1.267	1.319	1.317	1.330	1.281	1.324	1.265	1.274	1.270	1.305	1.305	1.350	1.331	1.358	1.208	1.311
K	0.076	0.066	0.067	0.065	0.069	0.052	0.047	0.053	0.051	0.044	0.051	0.022	0.015	0.064	0.066	0.071	0.067	0.060	0.062	0.067	0.057	0.062	0.069
Total	15.631	15.580	15.575	15.599	15.648	15.544	15.524	15.504	15.562	15.396	15.541	15.179	15.149	15.390	15.415	15.417	15.470	15.399	15.401	15.481	15.528	15.316	15.473
$^{[B]}Na$	0.741	0.799	0.801	0.807	0.743	0.789	0.784	0.816	0.808	0.965	0.840	1.124	1.191	0.938	0.926	0.924	0.902	0.966	1.012	0.916	0.887	0.954	0.908
$^{[A]}Na$	0.555	0.514	0.508	0.534	0.580	0.492	0.477	0.451	0.511	0.351	0.490	0.157	0.134	0.326	0.348	0.346	0.403	0.339	0.339	0.415	0.470	0.254	0.404
XMg	0.623	0.641	0.623	0.624	0.559	0.636	0.616	0.584	0.604	0.686	0.531	0.669	0.649	0.937	0.878	0.882	0.877	0.909	0.841	0.901	0.873	1.000	0.897
XFe^{3+}	0.560	0.610	0.556	0.562	0.316	0.562	0.501	0.387	0.501	0.670	0.319	0.656	0.624	0.693	0.608	0.618	0.619	0.644	0.685	0.653	0.599	0.763	0.654

Table 2 Chemical compositions of amphibole (continued).

Sample No.	YB155	YB155	YB155	YB155	YB155	YB155	YB155	YB155	YB155	YB155	YB155	YB159	YB159	YB159	YB159	YB159	YB159	YB159	YB159	YB159	YB159	YB159	YB159
Rock type	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS
Grain No.	27	27	27	27	27	27	27	27	27	27	27	17	17	17	17	17	17	17	17	17	17	17	17
Point No.	51	52	53	54	55	56	57	58	59	60	61#	29	30	32	33	34	35	37	38	39	40	41	43
	core	core	core	core	mantle	mantle	mantle	mantle	mantle	mantle	mantle	core	core	core	core	core	core	core	core	mantle	mantle	mantle	mantle
	Ba	Ba	Ba	Ba	Ba	Ba	Ba	Wi	Wi	Wi	Wi	Ba	Ba	Ba	Ba	Ba	Ba	Ba	Ba	Ba	Ba	Ba	Ba
SiO_2	46.9	47.4	47.5	47.8	50.1	50.5	51.7	53.1	53.0	53.2	53.2	49.0	48.9	48.9	48.1	49.0	49.5	49.2	49.1	49.6	50.1	50.5	51.3
TiO_2	0.23	0.27	0.21	0.17	0.13	0.19	0.11	0.08	0.04	0.00	0.04	0.23	0.20	0.22	0.17	0.22	0.17	0.23	0.13	0.18	0.16	0.12	0.12
Al_2O_3	9.73	10.6	10.5	10.3	8.29	7.69	6.39	4.14	4.20	3.70	3.59	9.12	9.71	8.96	8.79	8.78	8.09	7.33	7.52	7.13	6.77	6.52	5.86
Cr_2O_3	0.00	0.00	0.00	0.01	0.06	0.04	0.01	0.00	0.03	0.00	0.02	0.02	0.00	0.03	0.01	0.00	0.00	0.00	0.00	0.04	0.01	0.02	0.00
FeO*	12.3	11.6	11.6	12.4	11.4	11.6	12.4	13.4	14.2	14.8	15.5	16.7	17.0	17.2	17.4	16.5	16.8	15.9	16.7	16.4	16.5	16.5	16.5
MnO	0.95	0.99	1.07	0.75	0.70	0.69	0.64	0.66	0.63	0.82	0.72	0.46	0.49	0.57	0.40	0.50	0.56	0.43	0.49	0.47	0.46	0.45	0.48
MgO	13.1	13.3	13.1	12.9	14.4	14.2	14.2	13.5	13.7	13.3	12.9	9.91	9.40	9.95	9.98	10.8	10.5	11.5	11.1	11.5	11.4	11.3	11.7
CaO	6.87	7.02	7.06	7.54	7.65	6.80	7.15	7.01	7.01	6.45	6.50	5.62	4.87	5.12	6.38	6.72	6.03	7.21	7.20	7.14	7.03	6.81	6.26
Na_2O	4.73	4.73	4.86	4.71	4.22	4.33	3.81	3.79	3.96	3.29	3.66	5.13	5.74	5.54	4.52	4.81	4.67	4.33	4.43	3.60	3.62	4.40	4.41
K_2O	0.37	0.36	0.33	0.25	0.16	0.12	0.14	0.12	0.08	0.13	0.09	0.24	0.27	0.20	0.30	0.29	0.20	0.23	0.23	0.18	0.19	0.16	0.11
Total	95.2	96.3	96.2	96.8	97.1	96.2	96.6	95.8	96.9	95.7	96.2	96.4	96.6	96.7	96.1	97.6	96.5	96.4	96.9	96.2	96.2	96.8	96.7
Fe_2O_3	9.56	9.04	8.05	7.08	7.90	9.03	8.81	6.16	7.86	10.7	9.36	7.47	7.55	9.01	8.38	7.22	8.54	6.80	7.09	9.52	9.00	6.91	8.75
FeO	3.70	3.47	4.35	6.03	4.29	3.47	4.47	7.86	7.13	5.18	7.07	9.98	10.2	9.09	9.86	10.0	9.12	9.78	10.3	7.83	8.40	10.3	8.63
New total	96.1	97.2	97.0	97.5	97.9	97.1	97.4	96.4	97.6	96.8	97.2	97.2	97.3	97.6	96.9	98.3	97.4	97.0	97.6	97.2	97.1	97.5	97.6
	Atomic ratios (O=23)																						
Si	6.838	6.812	6.848	6.881	7.110	7.199	7.353	7.676	7.585	7.645	7.661	7.152	7.131	7.115	7.076	7.091	7.203	7.201	7.173	7.210	7.286	7.350	7.415
$^{[4]}Al$	1.162	1.188	1.152	1.119	0.890	0.801	0.647	0.324	0.415	0.355	0.339	0.848	0.869	0.885	0.924	0.909	0.797	0.799	0.827	0.790	0.714	0.650	0.585
$^{[6]}Al$	0.510	0.607	0.632	0.628	0.496	0.491	0.424	0.381	0.293	0.272	0.270	0.721	0.800	0.651	0.601	0.588	0.590	0.466	0.467	0.432	0.446	0.469	0.413
Ti	0.025	0.029	0.023	0.018	0.014	0.020	0.012	0.009	0.004	0.000	0.004	0.025	0.022	0.024	0.019	0.024	0.019	0.025	0.014	0.020	0.017	0.013	0.013
Cr	0.000	0.000	0.000	0.001	0.007	0.005	0.001	0.000	0.003	0.000	0.002	0.002	0.000	0.003	0.001	0.000	0.000	0.000	0.000	0.005	0.001	0.002	0.000
Fe^{3+}	1.049	0.977	0.874	0.767	0.844	0.969	0.943	0.670	0.846	1.156	1.015	0.820	0.829	0.986	0.927	0.786	0.935	0.749	0.780	1.042	0.985	0.757	0.952
Fe^{2+}	0.451	0.417	0.525	0.726	0.509	0.414	0.532	0.950	0.853	0.623	0.852	1.218	1.244	1.107	1.213	1.210	1.110	1.197	1.261	0.952	1.022	1.251	1.043
Mn	0.117	0.121	0.131	0.091	0.084	0.083	0.077	0.081	0.076	0.100	0.088	0.057	0.061	0.070	0.050	0.061	0.069	0.053	0.061	0.058	0.057	0.055	0.059
Mg	2.847	2.849	2.816	2.768	3.046	3.018	3.011	2.909	2.923	2.849	2.769	2.156	2.044	2.158	2.189	2.330	2.278	2.509	2.417	2.492	2.472	2.452	2.521
Ca	1.073	1.081	1.091	1.163	1.163	1.039	1.090	1.086	1.075	0.993	1.003	0.879	0.761	0.798	1.006	1.042	0.940	1.131	1.127	1.112	1.095	1.062	0.969
Na	1.337	1.318	1.359	1.315	1.161	1.197	1.051	1.062	1.099	0.917	1.022	1.452	1.623	1.563	1.289	1.350	1.318	1.229	1.255	1.015	1.021	1.242	1.236
K	0.069	0.066	0.061	0.046	0.029	0.022	0.025	0.022	0.015	0.024	0.017	0.045	0.050	0.037	0.056	0.054	0.037	0.043	0.043	0.033	0.035	0.030	0.020
Total	15.479	15.465	15.510	15.523	15.353	15.257	15.166	15.170	15.188	14.934	15.041	15.375	15.434	15.398	15.351	15.445	15.295	15.402	15.425	15.160	15.151	15.333	15.226
$^{[B]}Na$	0.927	0.919	0.909	0.837	0.837	0.961	0.910	0.914	0.925	0.917	0.997	1.121	1.239	1.202	0.994	0.958	1.060	0.869	0.873	0.888	0.905	0.938	1.031
$^{[A]}Na$	0.410	0.399	0.449	0.477	0.324	0.235	0.140	0.148	0.174	0.000	0.025	0.331	0.384	0.361	0.295	0.391	0.258	0.360	0.382	0.127	0.116	0.304	0.205
XMg	0.863	0.872	0.843	0.792	0.857	0.879	0.850	0.754	0.774	0.821	0.765	0.639	0.622	0.661	0.643	0.658	0.672	0.677	0.657	0.724	0.707	0.662	0.707
XFe^{3+}	0.673	0.617	0.580	0.550	0.630	0.664	0.690	0.637	0.743	0.809	0.790	0.532	0.509	0.602	0.607	0.572	0.613	0.617	0.625	0.707	0.688	0.618	0.697

Table 2 Chemical compositions of amphibole (continued).

Sample No.	YB159	YB159	YB159	YB159	YB159	YB159	YB159	YB159	YB159	YB159	YB159	YB159	YB159	YB159	YB159	YB159	YB159	YB159	YB35	YB35	YB35	YB35	YB35
Rock type	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	BS	BS	BS	BS	BS
Grain No.	17	17	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	2,2	2,2	2,2	2,2	2,2
Point No.	44	46#	93	96	97	98	99	100	101	102	103	104	105	106	107	108	110#	111	21	22	23	24	25
	mantle	mantle	core	core	core	core	core	core	core	core	core	core	core	mantle	mantle	mantle	mantle	mantle	core	core	core	core	core
	Ba	Wi	Ba	Ba	Ba	Ba	Ba	Ba	Ba	Ba	Ba	Ba	Ba	Ba	Ba	Ba	Wi	Wi	Ba	Ba	Ba	Ba	Ba
SiO_2	51.0	52.2	48.5	48.1	47.4	47.7	47.2	46.3	45.7	46.9	46.2	46.1	45.8	46.2	48.3	49.3	51.2	51.8	45.4	45.9	45.4	45.4	45.6
TiO_2	0.11	0.04	0.19	0.21	0.19	0.20	0.20	0.12	0.23	0.15	0.20	0.22	0.21	0.19	0.20	0.18	0.08	0.09	0.35	0.37	0.44	0.42	0.25
Al_2O_3	5.56	4.51	10.0	10.6	10.2	10.1	10.6	11.2	11.0	10.3	11.2	11.2	11.1	10.5	8.42	7.44	5.63	4.98	11.6	11.8	11.6	11.8	10.8
Cr_2O_3	0.00	0.01	0.04	0.00	0.00	0.00	0.00	0.04	0.11	0.01	0.00	0.01	0.00	0.07	0.13	0.01	0.00	0.00	0.00	0.00	0.05	0.02	0.00
FeO*	16.9	18.0	16.4	16.5	16.7	17.2	17.2	16.7	17.1	17.1	17.3	17.3	17.4	17.3	16.7	17.3	17.5	17.5	17.2	17.2	17.5	17.5	17.3
MnO	0.49	0.34	0.60	0.56	0.58	0.56	0.55	0.47	0.51	0.59	0.46	0.57	0.61	0.49	0.52	0.55	0.54	0.46	0.48	0.33	0.31	0.35	0.28
MgO	11.2	10.9	9.40	9.78	9.44	9.92	9.55	9.41	9.15	9.64	9.57	9.27	9.37	9.21	10.5	10.5	10.5	10.9	9.57	9.89	9.88	9.72	9.82
CaO	6.03	4.82	5.25	4.88	5.05	5.17	5.54	6.09	6.29	6.74	6.27	6.78	6.82	6.81	6.77	6.44	5.55	5.79	8.75	8.49	8.34	8.59	8.22
Na_2O	4.31	4.84	5.49	5.83	5.52	5.45	4.81	5.41	5.15	4.91	5.03	4.96	4.94	4.31	4.33	4.37	4.64	4.37	3.94	3.94	3.96	3.85	3.63
K_2O	0.09	0.14	0.23	0.26	0.27	0.24	0.27	0.31	0.32	0.29	0.32	0.29	0.33	0.32	0.28	0.28	0.16	0.12	0.42	0.48	0.51	0.55	0.39
Total	95.7	95.8	96.1	96.7	95.4	96.5	95.9	96.1	95.6	96.6	96.6	96.7	96.6	95.4	96.2	96.4	95.8	96.0	97.7	98.4	98.0	98.2	96.3
Fe_2O_3	8.81	9.93	6.87	8.97	8.71	10.6	10.7	7.26	7.49	7.16	9.20	7.32	7.83	7.93	8.00	8.42	8.14	8.38	5.40	6.61	7.52	6.76	7.60
FeO	8.97	9.07	10.2	8.43	8.86	7.65	7.54	10.2	10.4	10.7	9.02	10.7	10.4	10.2	9.50	9.72	10.2	9.96	12.3	11.3	10.7	11.4	10.5
New total	96.6	96.8	96.8	97.6	96.2	97.6	97.0	96.8	96.4	97.4	97.5	97.4	97.4	96.2	97.0	97.2	96.6	96.9	98.2	99.1	98.7	98.9	97.1
	Atomic ratios (O=23)																						
Si	7.459	7.612	7.108	6.978	6.995	6.936	6.900	6.839	6.805	6.902	6.773	6.791	6.760	6.873	7.092	7.217	7.509	7.565	6.677	6.668	6.626	6.627	6.747
$^{[4]}Al$	0.541	0.388	0.892	1.022	1.005	1.064	1.100	1.161	1.195	1.098	1.227	1.209	1.240	1.127	0.908	0.783	0.491	0.435	1.323	1.332	1.374	1.373	1.253
$^{[6]}Al$	0.418	0.388	0.836	0.791	0.769	0.667	0.726	0.788	0.736	0.689	0.708	0.736	0.691	0.714	0.549	0.501	0.482	0.423	0.688	0.688	0.622	0.657	0.630
Ti	0.012	0.004	0.021	0.023	0.021	0.022	0.022	0.013	0.026	0.017	0.022	0.024	0.023	0.021	0.022	0.020	0.009	0.010	0.039	0.040	0.048	0.046	0.028
Cr	0.000	0.001	0.005	0.000	0.000	0.000	0.000	0.005	0.013	0.001	0.000	0.001	0.000	0.008	0.015	0.001	0.000	0.000	0.000	0.000	0.006	0.002	0.000
Fe^{3+}	0.970	1.089	0.757	0.979	0.967	1.161	1.181	0.806	0.839	0.793	1.015	0.811	0.870	0.888	0.884	0.928	0.898	0.921	0.598	0.722	0.826	0.743	0.846
Fe^{2+}	1.098	1.106	1.253	1.023	1.094	0.931	0.922	1.256	1.291	1.312	1.106	1.320	1.278	1.265	1.166	1.190	1.248	1.217	1.518	1.367	1.311	1.393	1.295
Mn	0.061	0.042	0.074	0.069	0.072	0.069	0.068	0.059	0.064	0.074	0.057	0.071	0.076	0.062	0.065	0.068	0.067	0.057	0.060	0.041	0.038	0.043	0.035
Mg	2.442	2.370	2.054	2.115	2.077	2.150	2.081	2.072	2.031	2.115	2.092	2.036	2.062	2.043	2.298	2.292	2.296	2.373	2.098	2.142	2.150	2.115	2.166
Ca	0.945	0.753	0.824	0.759	0.798	0.805	0.868	0.964	1.004	1.063	0.985	1.070	1.079	1.085	1.065	1.010	0.872	0.906	1.379	1.321	1.304	1.343	1.303
Na	1.222	1.369	1.560	1.640	1.579	1.537	1.363	1.549	1.487	1.401	1.430	1.417	1.414	1.243	1.233	1.240	1.319	1.237	1.124	1.110	1.121	1.090	1.041
K	0.017	0.026	0.043	0.048	0.051	0.045	0.050	0.058	0.061	0.054	0.060	0.055	0.062	0.061	0.052	0.052	0.030	0.022	0.079	0.089	0.095	0.102	0.074
Total	15.184	15.148	15.428	15.447	15.429	15.387	15.281	15.572	15.551	15.518	15.474	15.541	15.554	15.389	15.350	15.303	15.221	15.166	15.581	15.520	15.520	15.535	15.418
$^{[B]}Na$	1.055	1.247	1.176	1.241	1.202	1.195	1.132	1.036	0.996	0.937	1.015	0.930	0.921	0.915	0.935	0.990	1.128	1.094	0.621	0.679	0.696	0.657	0.697
$^{[A]}Na$	0.167	0.122	0.385	0.399	0.378	0.342	0.231	0.513	0.491	0.464	0.415	0.487	0.492	0.329	0.298	0.251	0.192	0.144	0.502	0.431	0.425	0.433	0.344
XMg	0.690	0.682	0.621	0.674	0.655	0.698	0.693	0.623	0.612	0.617	0.654	0.607	0.617	0.618	0.663	0.658	0.648	0.661	0.580	0.610	0.621	0.603	0.626
XFe^{3+}	0.699	0.738	0.475	0.553	0.557	0.635	0.619	0.506	0.533	0.535	0.589	0.524	0.557	0.554	0.617	0.649	0.651	0.685	0.465	0.512	0.570	0.531	0.573

Table 2 Chemical compositions of amphibole (continued).

Sample No.	YB35	YB35	YB35	YB35	YB35	YB35	YB35	YB35	YB35	YB35	YB35	YB35	YB35	YB35	YB35	YB35	YB35	YB35	YB35	YB35	YB35	YB35	YB35
Rock type	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS
Grain No.	2,2	2,2	2,2	2,2	2,2	2,2	2,2	3,3	3,3	3,3	3,3	3,3	3,3	3,3	3,3	3,3	3,3	7,5	7,5	7,5	7,5	7,5	7,5
Point No.	26	27	28	29	30	31	32#	43	44	45	46	47	48	49#	51	52	53	67	68	70	71	72	73
	core	core	mantle	mantle	mantle	mantle	mantle	core	core	core	core	core	core	mantle	mantle	mantle	mantle	core	core	core	mantle	mantle	mantle
	Ba	Ba	Wi	Wi	Wi	Wi	Mrb	Ba	Ba	Ba	Ba	Ba	Ba	Wi	Wi	Wi	Wi	Ba	Ba	Ba	Wi	Wi	Wi
SiO_2	45.5	46.1	52.1	53.5	53.9	54.6	54.6	46.3	46.3	45.5	46.7	46.6	45.7	52.1	51.3	53.4	53.7	45.8	46.0	45.9	53.0	53.6	53.6
TiO_2	0.29	0.34	0.13	0.07	0.04	0.04	0.05	0.30	0.31	0.19	0.33	0.22	0.22	0.06	0.06	0.03	0.06	0.38	0.33	0.33	0.10	0.05	0.03
Al_2O_3	11.2	10.7	4.83	3.30	3.36	3.46	3.84	10.5	10.6	11.3	10.2	10.3	10.9	3.98	3.74	2.04	1.74	10.9	10.9	11.2	3.88	3.34	3.25
Cr_2O_3	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.05	0.00	0.02	0.01	0.01	0.00	0.00	0.02	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.02
FeO*	17.4	17.4	19.1	18.7	20.2	20.9	21.2	16.6	16.9	18.0	17.6	17.6	17.6	20.0	20.0	19.4	18.7	17.9	17.3	18.2	19.9	21.0	21.7
MnO	0.37	0.24	0.22	0.16	0.11	0.15	0.10	0.32	0.35	0.35	0.35	0.42	0.29	0.18	0.26	0.21	0.21	0.28	0.30	0.23	0.17	0.25	0.14
MgO	9.53	9.83	10.3	10.5	10.2	9.39	9.30	10.3	9.90	9.44	9.86	9.70	9.42	9.76	10.4	11.5	11.7	9.48	9.85	9.66	10.3	9.00	9.08
CaO	8.40	8.34	6.35	6.12	4.76	4.08	3.02	8.42	7.92	8.14	8.20	7.83	8.17	6.17	8.76	8.94	9.54	8.72	8.59	8.29	5.06	4.03	4.01
Na_2O	3.85	4.08	4.08	4.22	4.92	5.27	5.52	3.48	3.72	3.76	3.98	3.84	4.19	3.97	2.44	2.47	2.20	3.92	3.97	4.11	4.45	4.85	5.08
K_2O	0.39	0.37	0.18	0.13	0.10	0.04	0.08	0.34	0.31	0.36	0.29	0.28	0.32	0.15	0.32	0.12	0.10	0.48	0.49	0.43	0.08	0.09	0.08
Total	96.9	97.4	97.4	96.7	97.6	97.9	97.7	96.6	96.3	97.1	97.5	96.8	96.8	96.4	97.3	98.2	98.0	97.9	97.7	98.4	96.9	96.2	97.0
Fe_2O_3	6.34	5.83	7.62	5.67	9.17	8.76	11.5	7.16	7.41	8.22	6.47	7.73	5.76	7.58	6.24	5.54	3.50	5.16	5.43	7.17	10.4	9.56	10.2
FeO	11.7	12.2	12.2	13.6	12.0	13.0	10.8	10.2	10.2	10.6	11.8	10.6	12.4	13.2	14.4	14.4	15.6	13.3	12.4	11.7	10.5	12.4	12.5
New total	97.6	98.0	98.1	97.3	98.6	98.8	98.8	97.4	97.0	97.9	98.2	97.5	97.4	97.2	97.9	98.7	98.4	98.4	98.3	99.0	97.9	97.2	98.0
	Atomic ratios (O=23)																						
Si	6.722	6.781	7.572	7.826	7.778	7.859	7.814	6.805	6.823	6.691	6.845	6.849	6.773	7.674	7.560	7.764	7.839	6.745	6.757	6.692	7.673	7.850	7.805
$^{[4]}Al$	1.278	1.219	0.428	0.174	0.222	0.141	0.186	1.195	1.177	1.309	1.155	1.151	1.227	0.326	0.440	0.236	0.161	1.255	1.243	1.308	0.327	0.150	0.195
$^{[6]}Al$	0.673	0.636	0.399	0.395	0.350	0.446	0.461	0.624	0.664	0.650	0.607	0.633	0.677	0.364	0.209	0.114	0.138	0.637	0.644	0.617	0.336	0.426	0.363
Ti	0.032	0.038	0.014	0.008	0.004	0.004	0.005	0.033	0.034	0.021	0.036	0.024	0.025	0.007	0.007	0.003	0.007	0.042	0.036	0.036	0.011	0.006	0.003
Cr	0.000	0.000	0.007	0.000	0.000	0.000	0.000	0.006	0.000	0.002	0.001	0.001	0.000	0.000	0.002	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.002
Fe^{3+}	0.705	0.645	0.834	0.624	0.996	0.949	1.242	0.792	0.822	0.910	0.713	0.855	0.643	0.840	0.692	0.606	0.384	0.572	0.600	0.787	1.135	1.054	1.122
Fe^{2+}	1.445	1.495	1.488	1.664	1.442	1.567	1.295	1.249	1.261	1.304	1.444	1.309	1.539	1.624	1.773	1.753	1.899	1.632	1.525	1.432	1.274	1.518	1.521
Mn	0.046	0.030	0.027	0.020	0.013	0.018	0.012	0.040	0.044	0.044	0.043	0.052	0.036	0.022	0.032	0.026	0.026	0.035	0.037	0.028	0.021	0.031	0.017
Mg	2.099	2.156	2.232	2.290	2.194	2.015	1.984	2.257	2.175	2.070	2.155	2.125	2.081	2.143	2.285	2.493	2.546	2.081	2.157	2.100	2.223	1.965	1.971
Ca	1.330	1.314	0.989	0.959	0.736	0.629	0.463	1.326	1.251	1.283	1.288	1.233	1.297	0.974	1.383	1.393	1.492	1.376	1.352	1.295	0.785	0.632	0.626
Na	1.103	1.164	1.150	1.197	1.377	1.471	1.532	0.992	1.063	1.072	1.131	1.094	1.204	1.134	0.697	0.696	0.623	1.119	1.131	1.162	1.249	1.377	1.434
K	0.074	0.069	0.033	0.024	0.018	0.007	0.015	0.064	0.058	0.068	0.054	0.053	0.061	0.028	0.060	0.022	0.019	0.090	0.092	0.080	0.015	0.017	0.015
Total	15.506	15.548	15.172	15.180	15.131	15.107	15.009	15.381	15.372	15.422	15.473	15.380	15.562	15.136	15.140	15.111	15.133	15.585	15.574	15.537	15.049	15.026	15.075
$^{[B]}Na$	0.670	0.686	1.011	1.041	1.264	1.371	1.532	0.674	0.749	0.717	0.712	0.767	0.703	1.026	0.617	0.607	0.508	0.624	0.648	0.705	1.215	1.368	1.374
$^{[A]}Na$	0.433	0.478	0.138	0.156	0.113	0.100	0.000	0.318	0.313	0.355	0.419	0.327	0.501	0.107	0.080	0.089	0.115	0.495	0.483	0.457	0.034	0.010	0.060
XMg	0.592	0.590	0.600	0.579	0.603	0.563	0.605	0.644	0.633	0.613	0.599	0.619	0.575	0.569	0.563	0.587	0.573	0.560	0.586	0.595	0.636	0.564	0.565
XFe^{3+}	0.512	0.503	0.676	0.612	0.740	0.680	0.729	0.559	0.553	0.583	0.540	0.574	0.487	0.697	0.768	0.842	0.735	0.473	0.482	0.561	0.772	0.712	0.755

Table 2 Chemical compositions of amphibole (continued).

Sample No.	YB35	YB35	YB46	YB46	YB46	YB46	YB46	YB46	YB46	YB46	YB46	YB46	YB46	YB46	YB46	YB46	YB46	YB46	YB46	YB46	YB46	YB46	YB46
Rock type	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS
Grain No.	7,5	7,5	13,2	13,2	13,2	13,2	13,2	13,2	13,2	13,2	13,2	13,2	13,2	13,2	13,2	13,2	13,2	13,2	13,2	13,2	13,2	13,2	18,3
Point No.	74#	75	42	43	44	45	46	47	48	49	50	51#	52	53	54	55	56	57	58	59	60	61	83
	mantle	mantle	core	core	core	core	core	core	core	mantle	mantle	mantle	mantle	mantle	mantle	mantle	mantle	mantle	mantle	mantle	mantle	mantle	core
	Wi	Wi	Ba	Ba	Ba	Ba	Ba	Ba	Ba	Ba	Mrb	Mrb	Wi	Wi	Wi	Wi	Wi	Wi	Act	Act	Act	Act	Ba
SiO_2	53.8	54.0	46.6	46.7	47.4	47.5	47.2	46.5	46.2	48.4	54.4	56.4	55.5	54.3	54.9	55.3	54.7	53.8	55.3	55.4	55.2	54.2	47.1
TiO_2	0.04	0.03	0.46	0.48	0.37	0.42	0.42	0.41	0.35	0.19	0.11	0.04	0.07	0.11	0.04	0.06	0.09	0.01	0.00	0.01	0.00	0.05	0.37
Al_2O_3	3.46	3.17	10.4	9.95	9.88	9.84	9.88	9.84	10.0	7.94	6.59	3.47	2.77	2.31	2.48	2.73	2.18	2.94	1.72	1.81	0.84	2.02	9.71
Cr_2O_3	0.03	0.00	0.00	0.03	0.00	0.02	0.00	0.03	0.03	0.03	0.00	0.00	0.00	0.01	0.00	0.00	0.04	0.00	0.00	0.03	0.06	0.00	0.03
FeO*	21.9	19.8	15.8	15.5	15.2	16.2	16.0	15.5	16.1	17.1	16.7	18.2	15.8	13.5	13.5	14.1	12.7	13.7	11.5	12.6	12.5	12.8	14.2
MnO	0.14	0.24	0.00	0.05	0.11	0.08	0.04	0.11	0.05	0.06	0.08	0.05	0.10	0.18	0.18	0.16	0.16	0.23	0.21	0.23	0.26	0.19	0.22
MgO	8.74	9.96	11.3	11.0	11.1	11.3	11.3	11.3	10.8	11.1	10.7	10.9	12.9	15.1	14.5	14.6	15.2	14.8	16.5	16.7	15.9	15.4	11.7
CaO	3.56	5.66	7.74	7.74	7.82	7.85	7.93	8.40	8.37	7.68	2.90	1.76	4.30	8.46	8.00	7.83	9.68	9.56	10.4	10.3	10.2	9.78	8.48
Na_2O	5.57	4.40	4.31	4.24	4.39	4.41	4.16	4.01	4.01	3.57	6.05	6.32	4.95	2.82	3.25	3.00	2.18	2.40	1.66	1.63	1.67	1.98	3.86
K_2O	0.08	0.12	0.57	0.51	0.47	0.41	0.48	0.55	0.57	0.32	0.08	0.04	0.04	0.07	0.07	0.05	0.12	0.11	0.06	0.08	0.07	0.07	0.50
Total	97.3	97.4	97.2	96.2	96.7	98.0	97.4	96.7	96.5	96.4	97.6	97.2	96.4	96.9	96.9	97.8	97.1	97.6	97.4	98.8	96.7	96.5	96.2
Fe_2O_3	9.62	6.51	7.32	5.83	4.72	6.85	6.94	5.55	5.35	8.50	9.46	11.4	9.70	6.54	4.71	7.13	3.20	4.81	3.85	6.73	3.70	4.52	4.53
FeO	13.2	13.9	9.21	10.3	11.0	10.0	9.75	10.5	11.3	9.45	8.19	7.96	7.07	7.62	9.26	7.69	9.82	9.37	8.03	6.54	9.17	8.73	10.1
New total	98.2	98.0	97.9	96.8	97.3	98.7	98.1	97.2	97.0	97.2	98.6	98.3	97.4	97.5	97.4	98.6	97.4	98.0	97.7	99.5	97.1	96.9	96.6
	Atomic ratios (O=23)																						
Si	7.824	7.855	6.787	6.882	6.949	6.869	6.862	6.844	6.834	7.084	7.667	7.967	7.898	7.751	7.850	7.792	7.833	7.687	7.838	7.728	7.919	7.791	6.930
$^{[4]}Al$	0.176	0.145	1.213	1.118	1.051	1.131	1.138	1.156	1.166	0.916	0.333	0.033	0.102	0.249	0.150	0.208	0.167	0.313	0.162	0.272	0.081	0.209	1.070
$^{[6]}Al$	0.417	0.399	0.572	0.610	0.656	0.547	0.555	0.550	0.578	0.453	0.762	0.544	0.363	0.140	0.268	0.246	0.201	0.182	0.125	0.026	0.061	0.133	0.614
Ti	0.004	0.003	0.050	0.053	0.041	0.046	0.046	0.045	0.039	0.021	0.012	0.004	0.007	0.012	0.004	0.006	0.010	0.001	0.000	0.001	0.000	0.005	0.041
Cr	0.003	0.000	0.000	0.003	0.000	0.002	0.000	0.003	0.004	0.003	0.000	0.000	0.000	0.001	0.000	0.000	0.005	0.000	0.000	0.003	0.007	0.000	0.003
Fe^{3+}	1.053	0.712	0.802	0.646	0.521	0.745	0.759	0.615	0.596	0.936	1.004	1.209	1.039	0.702	0.507	0.756	0.345	0.518	0.411	0.707	0.400	0.489	0.501
Fe^{2+}	1.611	1.696	1.122	1.264	1.343	1.214	1.186	1.293	1.396	1.157	0.965	0.941	0.841	0.909	1.107	0.906	1.176	1.119	0.952	0.763	1.100	1.050	1.246
Mn	0.017	0.030	0.000	0.006	0.014	0.010	0.005	0.014	0.006	0.007	0.010	0.006	0.012	0.022	0.022	0.019	0.019	0.028	0.025	0.027	0.032	0.023	0.027
Mg	1.895	2.160	2.453	2.417	2.426	2.436	2.449	2.479	2.382	2.422	2.248	2.295	2.737	3.214	3.091	3.067	3.245	3.152	3.486	3.473	3.401	3.300	2.566
Ca	0.555	0.882	1.208	1.222	1.228	1.216	1.235	1.325	1.327	1.204	0.438	0.266	0.656	1.294	1.226	1.182	1.485	1.463	1.579	1.539	1.568	1.506	1.337
Na	1.571	1.241	1.217	1.212	1.248	1.237	1.173	1.144	1.150	1.013	1.653	1.731	1.366	0.781	0.901	0.820	0.605	0.665	0.456	0.441	0.465	0.552	1.101
K	0.015	0.022	0.106	0.096	0.088	0.076	0.089	0.103	0.108	0.060	0.014	0.007	0.007	0.013	0.013	0.009	0.022	0.020	0.011	0.014	0.013	0.013	0.094
Total	15.140	15.145	15.531	15.529	15.564	15.529	15.497	15.572	15.584	15.277	15.106	15.004	15.029	15.087	15.140	15.011	15.112	15.148	15.046	14.995	15.045	15.071	15.532
$^{[B]}Na$	1.445	1.118	0.792	0.778	0.772	0.784	0.765	0.675	0.673	0.796	1.562	1.731	1.344	0.706	0.774	0.818	0.515	0.537	0.421	0.441	0.432	0.494	0.663
$^{[A]}Na$	0.125	0.123	0.425	0.434	0.476	0.453	0.408	0.469	0.477	0.217	0.091	0.000	0.022	0.074	0.127	0.002	0.090	0.128	0.036	0.000	0.032	0.058	0.438
XMg	0.541	0.560	0.686	0.657	0.644	0.667	0.674	0.657	0.630	0.677	0.700	0.709	0.765	0.779	0.736	0.772	0.734	0.738	0.786	0.820	0.756	0.759	0.673
XFe^{3+}	0.716	0.641	0.584	0.514	0.443	0.577	0.578	0.528	0.508	0.674	0.568	0.690	0.741	0.834	0.654	0.755	0.632	0.740	0.766	0.965	0.867	0.786	0.449

Table 2 Chemical compositions of amphibole (continued).

Sample No.	YB46	YB46	YB46	YB46	YB46	YB46	YB46	YB46	YB46	YB46	YB46	YB46	YB46	YB46
Rock type	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS
Grain No.	18,3	18,3	18,3	18,3	18,3	18,3	18,3	18,3	18,3	18,3	18,3	18,3	18,3	18,3
Point No.	84	85	86	87	88	89	90#	91	92	93	94	95	96	97
	core	core	core	core	core	mantle	mantle	mantle	mantle	mantle	mantle	mantle	mantle	mantle
	Ba	Ba	Ba	Ba	Ba	Wi	Wi	Wi	Wi	Wi	Wi	Act	Act	Act
SiO_2	47.1	47.2	47.3	47.4	47.3	55.9	55.9	55.9	55.9	54.6	54.0	55.0	56.1	56.4
TiO_2	0.37	0.38	0.39	0.47	0.40	0.05	0.03	0.04	0.03	0.00	0.01	0.01	0.02	0.05
Al_2O_3	9.60	9.58	9.71	9.48	9.82	2.26	2.62	2.62	2.31	2.58	1.85	1.65	0.77	0.69
Cr_2O_3	0.00	0.02	0.00	0.00	0.05	0.00	0.00	0.00	0.04	0.07	0.01	0.00	0.00	0.01
FeO*	15.0	16.0	16.0	15.4	15.4	16.5	16.4	15.5	15.4	14.5	13.2	13.8	12.6	12.9
MnO	0.19	0.18	0.19	0.10	0.10	0.21	0.18	0.20	0.18	0.26	0.29	0.31	0.30	0.36
MgO	12.0	11.4	11.4	11.7	11.5	12.9	13.0	13.1	13.4	14.2	14.9	15.4	16.6	15.6
CaO	8.37	7.82	8.16	8.51	8.53	4.46	3.68	4.41	4.79	8.13	9.16	9.82	11.0	9.93
Na_2O	3.88	3.88	3.87	3.88	3.97	4.79	5.36	4.85	4.74	3.13	2.20	1.68	1.33	1.46
K_2O	0.47	0.55	0.43	0.55	0.55	0.03	0.06	0.00	0.04	0.06	0.09	0.08	0.06	0.06
Total	97.0	97.0	97.5	97.5	97.6	97.1	97.2	96.6	96.8	97.5	95.7	97.8	98.8	97.5
Fe_2O_3	6.96	8.18	7.49	5.71	5.22	10.4	11.5	9.63	9.23	5.93	5.02	6.29	4.04	4.06
FeO	8.74	8.64	9.26	10.3	10.7	7.15	6.06	6.84	7.09	9.16	8.68	8.14	8.97	9.25
New total	97.7	97.8	98.2	98.1	98.1	98.2	98.4	97.6	97.8	98.1	96.2	98.4	99.2	97.9
	Atomic ratios (O=23)													
Si	6.858	6.870	6.865	6.898	6.884	7.915	7.877	7.927	7.926	7.782	7.827	7.796	7.879	8.004
$^{[4]}Al$	1.142	1.130	1.135	1.102	1.116	0.085	0.123	0.073	0.074	0.218	0.173	0.204	0.121	0.000
$^{[6]}Al$	0.505	0.513	0.526	0.524	0.569	0.292	0.312	0.364	0.312	0.215	0.143	0.072	0.007	0.115
Ti	0.041	0.042	0.043	0.051	0.044	0.005	0.003	0.004	0.003	0.000	0.001	0.001	0.002	0.005
Cr	0.000	0.002	0.000	0.000	0.006	0.000	0.000	0.000	0.004	0.008	0.001	0.000	0.000	0.001
Fe^{3+}	0.762	0.896	0.818	0.625	0.571	1.108	1.219	1.027	0.985	0.636	0.548	0.671	0.427	0.433
Fe^{2+}	1.064	1.051	1.124	1.249	1.303	0.846	0.714	0.811	0.841	1.092	1.052	0.965	1.053	1.098
Mn	0.023	0.022	0.023	0.012	0.012	0.025	0.021	0.024	0.022	0.031	0.036	0.037	0.036	0.043
Mg	2.605	2.474	2.467	2.538	2.495	2.723	2.731	2.769	2.832	3.017	3.219	3.254	3.476	3.300
Ca	1.306	1.219	1.269	1.327	1.330	0.677	0.556	0.670	0.728	1.242	1.422	1.491	1.655	1.510
Na	1.095	1.095	1.089	1.095	1.120	1.315	1.464	1.333	1.303	0.865	0.618	0.462	0.362	0.402
K	0.087	0.102	0.080	0.102	0.102	0.005	0.011	0.000	0.007	0.011	0.017	0.014	0.011	0.011
Total	15.488	15.416	15.437	15.524	15.553	14.997	15.031	15.003	15.038	15.117	15.057	14.968	15.028	14.922
$^{[B]}Na$	0.694	0.781	0.731	0.673	0.670	1.315	1.444	1.330	1.272	0.758	0.578	0.462	0.345	0.402
$^{[A]}Na$	0.401	0.314	0.358	0.422	0.450	0.000	0.020	0.003	0.031	0.106	0.041	0.000	0.017	0.000
XMg	0.710	0.702	0.687	0.670	0.657	0.763	0.793	0.773	0.771	0.734	0.754	0.771	0.767	0.750
XFe^{3+}	0.602	0.636	0.609	0.544	0.501	0.791	0.796	0.738	0.759	0.747	0.793	0.904	0.985	0.790

Table 3 Chemical compositions of epidote.

Sample No.	YB108	YB108	YB120	YB120	ST2204	ST2204	YB154	YB155	YB159	YB159	YB35	YB35	YB46	YB46
Rock type	BS	BS	QS	QS	BS	BS	QS	QS	QS	QS	BS	BS	BS	BS
Grain No.	7	7	2	2	7,1	7,1	16	25	34,1	34,2	2	2	11,1	16
Point No.	33	36	21	16	53	56	60	10	137	136	37	41	13	80
	core	rim			core	rim					core	rim		
SiO_2	38.4	37.5	37.3	37.6	37.2	38.2	37.2	37.1	37.5	37.3	37.2	37.6	37.1	38.1
TiO_2	0.04	0.10	0.05	0.01	0.07	0.09	0.06	0.08	0.16	0.05	0.08	0.08	0.12	0.08
Al_2O_3	25.7	22.6	23.1	22.4	22.6	23.7	21.2	22.5	21.6	21.5	22.4	23.8	22.3	24.0
Cr_2O_3	0.02	0.00	0.00	0.00	0.00	0.00	0.07	0.03	0.00	0.05	0.02	0.02	0.00	0.01
Fe_2O_3*	10.4	13.6	13.1	14.1	15.2	13.3	16.0	12.8	14.6	14.8	15.0	13.2	15.0	12.7
MnO	0.21	0.30	0.83	0.70	0.49	0.19	0.59	1.19	0.79	0.67	0.78	0.34	0.12	0.05
MgO	0.02	0.01	0.06	0.03	0.02	0.07	0.01	0.07	0.03	0.00	0.00	0.09	0.02	0.00
CaO	23.6	22.6	22.2	21.2	22.9	23.6	22.0	22.0	22.5	22.7	22.2	22.9	23.2	23.6
Na_2O	0.01	0.01	0.01	0.04	0.00	0.01	0.00	0.00	0.00	0.04	0.02	0.00	0.00	0.05
K_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.01	0.00
Total	98.4	96.7	96.7	96.1	98.5	99.2	97.1	95.8	97.2	97.1	97.7	98.0	97.9	98.6
	Atomic ratios (O=12.5)													
Si	3.008	3.026	3.010	3.049	2.969	3.002	3.016	3.026	3.030	3.021	2.989	2.988	2.978	3.006
Ti	0.002	0.006	0.003	0.001	0.004	0.005	0.004	0.005	0.010	0.003	0.005	0.005	0.007	0.005
Al	2.373	2.149	2.197	2.141	2.126	2.195	2.025	2.163	2.057	2.052	2.122	2.229	2.110	2.232
Cr	0.001	0.000	0.000	0.000	0.000	0.000	0.004	0.002	0.000	0.003	0.001	0.001	0.000	0.001
Fe^{3+}	0.613	0.823	0.796	0.861	0.914	0.789	0.976	0.784	0.885	0.901	0.907	0.791	0.906	0.752
Mn	0.014	0.021	0.057	0.048	0.033	0.013	0.041	0.082	0.054	0.046	0.053	0.023	0.008	0.003
Mg	0.002	0.001	0.007	0.004	0.002	0.008	0.001	0.009	0.004	0.000	0.000	0.011	0.002	0.000
Ca	1.981	1.954	1.919	1.842	1.958	1.987	1.911	1.923	1.948	1.970	1.911	1.950	1.995	1.995
Na	0.002	0.002	0.002	0.006	0.000	0.002	0.000	0.000	0.000	0.006	0.003	0.000	0.000	0.008
K	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.000	0.000	0.000	0.001	0.000
Total	7.997	7.982	7.991	7.952	8.007	8.001	7.978	7.994	7.991	8.001	7.992	7.997	8.008	8.001
YFe^{3+}	0.205	0.277	0.266	0.287	0.301	0.264	0.325	0.266	0.301	0.305	0.300	0.262	0.300	0.252

Table 4 Chemical compositions of chlorite.

Sample No.	YB108	YB108	YB120	YB120	ST2204	ST2204	ST2204	YB154	YB154	YB155	YB159	YB35	YB46	YB46
Rock type	BS	BS	QS	QS	BS	BS	BS	QS	QS	QS	QS	BS	BS	BS
Grain No.	7,1	7,2	5	1	11	16	17	12	13	29	31	3,1	11	16
Point No.	42	45	108	129	86	92	93	84	112	79	129	55	10	78
SiO_2	26.2	26.4	27.4	27.4	26.6	26.5	26.3	26.2	26.9	28.0	26.6	25.9	27.2	27.8
TiO_2	0.02	0.02	0.03	0.02	0.02	0.06	0.15	0.10	0.08	0.00	0.03	0.02	0.08	0.00
Al_2O_3	18.6	18.7	19.6	19.6	18.7	19.1	18.7	19.0	19.0	18.8	18.8	18.5	19.4	19.2
Cr_2O_3	0.00	0.00	0.03	0.04	0.04	0.04	0.00	0.00	0.00	0.01	0.05	0.02	0.00	0.00
FeO	23.2	24.5	17.6	18.4	24.2	22.4	24.3	23.2	24.0	16.8	21.9	28.7	19.5	17.9
MnO	0.45	0.45	0.77	0.99	0.45	0.42	0.58	0.41	0.51	0.99	1.04	0.40	0.26	0.26
MgO	16.8	16.2	20.1	20.1	16.5	17.4	16.5	16.8	16.3	21.4	17.3	13.2	19.6	20.1
CaO	0.04	0.03	0.03	0.00	0.09	0.07	0.08	0.02	0.01	0.04	0.04	0.03	0.01	0.02
Na_2O	0.00	0.00	0.00	0.01	0.00	0.00	0.02	0.00	0.00	0.03	0.03	0.00	0.00	0.00
K_2O	0.00	0.01	0.01	0.00	0.02	0.00	0.01	0.01	0.00	0.00	0.00	0.02	0.00	0.00
Total	85.3	86.3	85.6	86.6	86.6	86.0	86.6	85.7	86.8	86.1	85.8	86.8	86.1	85.3
	Atomic ratios (O=14)													
Si	2.818	2.822	2.843	2.826	2.828	2.810	2.802	2.801	2.846	2.880	2.830	2.819	2.830	2.889
$^{[4]}Al$	1.182	1.178	1.157	1.174	1.172	1.190	1.198	1.199	1.154	1.120	1.170	1.181	1.170	1.111
$^{[6]}Al$	1.175	1.179	1.241	1.209	1.172	1.198	1.150	1.195	1.215	1.159	1.187	1.192	1.208	1.241
Ti	0.002	0.002	0.002	0.002	0.002	0.005	0.012	0.008	0.006	0.000	0.002	0.002	0.006	0.000
Cr	0.000	0.000	0.002	0.003	0.003	0.003	0.000	0.000	0.000	0.001	0.004	0.002	0.000	0.000
Fe^{2+}	2.087	2.191	1.527	1.587	2.152	1.987	2.165	2.074	2.124	1.445	1.948	2.612	1.697	1.556
Mn	0.041	0.041	0.068	0.086	0.041	0.038	0.052	0.037	0.046	0.086	0.094	0.037	0.023	0.023
Mg	2.693	2.582	3.110	3.091	2.616	2.751	2.621	2.677	2.571	3.281	2.744	2.142	3.040	3.114
Ca	0.005	0.003	0.003	0.000	0.010	0.008	0.009	0.002	0.001	0.004	0.005	0.003	0.001	0.002
Na	0.000	0.000	0.000	0.002	0.000	0.000	0.004	0.000	0.000	0.006	0.006	0.000	0.000	0.000
K	0.000	0.001	0.001	0.000	0.003	0.000	0.001	0.001	0.000	0.000	0.000	0.003	0.000	0.000
Total	10.002	9.998	9.955	9.980	9.998	9.989	10.015	9.995	9.963	9.983	9.990	9.993	9.975	9.935
XMg	0.563	0.541	0.671	0.661	0.549	0.581	0.548	0.563	0.548	0.694	0.585	0.451	0.642	0.667

Table 5 Chemical compositions of garnet.

Sample No.	YB120	YB120	YB120	YB120	YB120	YB120	YB120	YB120	YB154	YB154	YB154	YB154	YB154	YB154
Rock type	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS
Grain No.	7	7	4	4	x	x	2	2	14	14	14	14	14	14
Point No.	5	2	146	142	161	153	166	164	13	2	58	53	64	60
	core	rim	core	rim	core	rim	core	rim	core	rim	core	rim	core	rim
SiO_2	36.5	37.3	36.4	37.3	36.7	37.0	36.9	37.3	37.4	37.4	37.3	37.6	37.7	37.1
TiO_2	0.11	0.04	0.16	0.14	0.19	0.10	0.11	0.10	0.09	0.01	0.12	0.07	0.08	0.05
Al_2O_3	19.8	20.9	19.8	20.8	19.6	20.7	20.0	20.6	20.9	21.3	20.6	21.1	20.8	20.5
Cr_2O_3	0.00	0.04	0.00	0.01	0.00	0.00	0.00	0.01	0.03	0.02	0.01	0.01	0.05	0.01
FeO*	12.8	18.2	13.7	18.7	12.3	17.1	13.9	17.2	26.5	27.9	26.1	27.1	27.4	27.9
MnO	22.9	15.0	22.8	14.7	24.4	17.0	24.6	16.5	8.06	5.96	7.94	6.45	6.57	5.51
MgO	0.72	1.81	0.67	1.85	0.42	1.30	0.84	1.35	1.37	2.21	1.27	2.20	1.63	1.99
CaO	5.64	6.08	5.52	6.63	6.42	6.67	4.43	6.98	5.95	5.83	6.90	6.05	6.61	6.18
Total	98.5	99.4	99.1	100.1	100.0	99.9	100.8	100.0	100.3	100.6	100.2	100.6	100.8	99.2
Fe_2O_3	1.18	0.10	1.42	0.63	2.02	0.63	1.65	0.76	0.24	0.14	0.76	0.31	0.65	0.72
FeO	11.7	18.1	12.4	18.1	10.5	16.5	12.4	16.5	26.3	27.8	25.4	26.8	26.8	27.3
New total	98.6	99.4	99.2	100.2	100.3	99.9	100.9	100.1	100.3	100.7	100.3	100.6	100.9	99.4
	Atomic ratios (O=12)													
Si	3.004	3.007	2.986	2.988	2.985	2.985	2.984	2.998	3.004	2.983	2.997	2.996	3.004	3.000
Ti	0.007	0.002	0.010	0.008	0.012	0.006	0.007	0.006	0.005	0.001	0.007	0.004	0.005	0.003
Al	1.920	1.986	1.915	1.964	1.879	1.968	1.906	1.951	1.978	2.002	1.951	1.981	1.954	1.954
Cr	0.000	0.003	0.000	0.001	0.000	0.000	0.000	0.001	0.002	0.001	0.001	0.001	0.003	0.001
Fe^{3+}	0.073	0.006	0.088	0.038	0.124	0.038	0.100	0.046	0.015	0.009	0.046	0.019	0.039	0.044
Fe^{2+}	0.808	1.221	0.852	1.215	0.713	1.115	0.840	1.110	1.765	1.852	1.708	1.787	1.787	1.843
Mn	1.596	1.024	1.584	0.998	1.681	1.161	1.685	1.123	0.548	0.403	0.540	0.435	0.443	0.377
Mg	0.088	0.218	0.082	0.221	0.051	0.156	0.101	0.162	0.164	0.263	0.152	0.261	0.194	0.240
Ca	0.497	0.525	0.485	0.569	0.559	0.576	0.384	0.601	0.512	0.498	0.594	0.516	0.564	0.535
Total	7.993	7.993	8.002	8.002	8.003	8.006	8.006	7.997	7.993	8.011	7.997	8.000	7.993	7.998

Table 5 Chemical compositions of garnet (continued).

Sample No.	YB154	YB154	YB155	YB155	YB155	YB155	YB159	YB159	YB159	YB159	YB159	YB159
Rock type	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS	QS
Grain No.	14	14	31	31	31	31	35	35	35	31	31	31
Point No.	74	67	21	17	26	23	34	31	30	47	40	38
	core	rim	core	rim	core	rim	core	inter	rim	core	inter	rim
SiO_2	37.5	37.3	37.4	37.5	36.9	37.9	36.9	37.6	37.4	36.7	37.4	37.1
TiO_2	0.10	0.05	0.08	0.07	0.09	0.06	0.18	0.07	0.05	0.11	0.05	0.04
Al_2O_3	20.8	21.0	21.0	21.0	20.6	21.0	20.3	20.8	20.9	20.5	20.6	20.8
Cr_2O_3	0.00	0.00	0.00	0.03	0.01	0.00	0.01	0.00	0.05	0.00	0.00	0.02
FeO*	26.1	27.2	12.7	14.1	12.3	13.6	9.16	23.8	26.9	7.60	21.9	26.7
MnO	8.67	6.16	23.0	18.7	21.6	18.9	28.2	10.3	8.52	30.0	11.9	8.41
MgO	1.17	2.58	2.31	2.71	2.06	2.70	0.81	1.35	2.01	0.65	1.31	2.04
CaO	6.37	5.35	4.01	5.55	4.80	6.10	4.77	6.81	4.71	4.75	6.75	3.71
Total	100.7	99.6	100.5	99.7	98.4	100.3	100.3	100.7	100.5	100.3	99.9	98.8
Fe_2O_3	0.51	0.22	0.38	0.26	0.20	0.43	1.05	0.62	0.43	0.84	0.62	0.00
FeO	25.6	27.0	12.4	13.9	12.1	13.2	8.21	23.2	26.5	6.84	21.3	26.7
New total	100.7	99.7	100.6	99.7	98.4	100.3	100.4	100.8	100.6	100.4	99.9	98.8
	Atomic ratios (O=12)											
Si	3.003	2.995	2.991	3.000	3.007	3.009	2.987	3.003	2.996	2.977	3.010	3.018
Ti	0.006	0.003	0.005	0.004	0.006	0.004	0.011	0.004	0.003	0.007	0.003	0.002
Al	1.963	1.988	1.980	1.980	1.979	1.965	1.937	1.958	1.973	1.960	1.954	1.994
Cr	0.000	0.000	0.000	0.002	0.001	0.000	0.001	0.000	0.003	0.000	0.000	0.001
Fe^{3+}	0.031	0.013	0.023	0.016	0.012	0.026	0.064	0.037	0.026	0.051	0.037	0.000
Fe^{2+}	1.717	1.813	0.827	0.928	0.826	0.877	0.556	1.552	1.776	0.464	1.437	1.816
Mn	0.588	0.419	1.558	1.267	1.491	1.271	1.934	0.697	0.578	2.061	0.811	0.579
Mg	0.140	0.309	0.275	0.323	0.250	0.320	0.098	0.161	0.240	0.079	0.157	0.247
Ca	0.547	0.460	0.344	0.476	0.419	0.519	0.414	0.583	0.404	0.413	0.582	0.323
Total	7.994	8.001	8.003	7.996	7.991	7.991	8.001	7.995	8.000	8.011	7.991	7.982

Table 6 Chemical compositions of muscovite.

Sample No.	YB108	YB108	YB120	YB120	ST2204	ST2204	ST2204	YB154	YB155	YB159	YB159	YB159	YB35	YB46
Rock type	BS	BS	QS	QS	BS	BS	BS	QS	QS	QS	QS	QS	BS	BS
Grain No.	8	8	6,1	6,2	17,1	17,2	11	17	25	20,1	20,2	25	2	12
Point No.	46	47	262	270	95	100	104	57	11	64	65	91	34	17
SiO_2	47.7	49.0	48.9	47.9	48.0	47.9	47.8	47.7	47.6	49.2	48.7	48.4	47.8	49.0
TiO_2	0.52	0.36	0.39	0.37	0.49	0.62	0.56	0.37	0.46	0.26	0.47	0.30	0.53	0.57
Al_2O_3	27.2	26.8	26.8	28.6	26.6	26.6	27.1	27.2	28.0	27.3	26.6	26.8	27.1	26.2
Cr_2O_3	0.00	0.03	0.02	0.00	0.02	0.03	0.05	0.02	0.00	0.00	0.00	0.00	0.00	0.00
FeO*	4.86	4.46	4.17	4.37	5.05	5.40	5.67	4.26	4.06	4.38	5.37	5.33	4.94	5.25
MnO	0.00	0.04	0.00	0.01	0.04	0.02	0.03	0.08	0.01	0.02	0.00	0.01	0.00	0.02
MgO	2.68	2.89	2.69	2.48	2.74	2.41	2.50	0.77	2.28	3.08	2.99	2.98	2.46	2.91
CaO	0.02	0.00	0.02	0.03	0.05	0.01	0.02	0.02	0.00	0.02	0.02	0.02	0.01	0.01
Na_2O	0.76	0.70	1.03	1.12	0.50	0.59	0.60	0.88	1.16	0.76	0.52	0.74	1.00	0.52
K_2O	11.1	11.4	10.9	10.1	11.7	11.2	11.4	10.7	10.5	10.6	11.1	10.4	10.7	11.4
Total	94.8	95.7	94.9	95.0	95.2	94.8	95.7	92.0	94.1	95.6	95.8	95.0	94.5	95.9
	Atomic ratios (O=11)													
Si	3.235	3.293	3.308	3.219	3.254	3.261	3.223	3.352	3.243	3.286	3.268	3.263	3.250	3.293
Ti	0.027	0.018	0.020	0.019	0.025	0.032	0.028	0.020	0.024	0.013	0.024	0.015	0.027	0.029
Al	2.174	2.122	2.137	2.265	2.126	2.135	2.153	2.253	2.248	2.149	2.104	2.130	2.172	2.075
Cr	0.000	0.002	0.001	0.000	0.001	0.002	0.003	0.001	0.000	0.000	0.000	0.000	0.000	0.000
Fe^{3+}	0.276	0.232	0.179	0.246	0.286	0.260	0.320	0.000	0.197	0.245	0.301	0.301	0.253	0.266
Fe^{2+}	0.000	0.019	0.057	0.000	0.000	0.047	0.000	0.250	0.034	0.000	0.000	0.000	0.028	0.029
Mn	0.000	0.002	0.000	0.001	0.002	0.001	0.002	0.005	0.001	0.001	0.000	0.001	0.000	0.001
Mg	0.271	0.290	0.271	0.248	0.277	0.245	0.251	0.081	0.232	0.307	0.299	0.300	0.249	0.292
Ca	0.001	0.000	0.001	0.002	0.004	0.001	0.001	0.002	0.000	0.001	0.001	0.001	0.001	0.001
Na	0.100	0.091	0.135	0.146	0.066	0.078	0.078	0.120	0.153	0.098	0.068	0.097	0.132	0.068
K	0.960	0.977	0.941	0.866	1.012	0.973	0.981	0.959	0.913	0.903	0.950	0.895	0.928	0.977
Total	7.044	7.046	7.051	7.012	7.053	7.034	7.040	7.041	7.044	7.004	7.015	7.002	7.040	7.030
XNa	0.094	0.085	0.126	0.144	0.061	0.074	0.074	0.111	0.144	0.098	0.066	0.098	0.124	0.065

Table 7 Chemical compositions of albite.

Sample No.	YB108	YB120	YB120	ST2204	YB154	YB155	YB159	YB35	YB35	YB46
Rock type	BS	QS	QS	BS	QS	QS	QS	BS	BS	BS
Grain No.	5	8	10	15	23	29	25	4	3	18
Point No.	40	98	142	84	1	78	86	1	54	101
SiO_2	69.0	70.1	70.0	69.2	69.7	68.2	68.8	69.6	69.5	69.7
TiO_2	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00
Al_2O_3	19.4	19.6	19.7	19.5	19.5	19.1	19.8	19.7	19.6	20.0
Cr_2O_3	0.00	0.04	0.00	0.01	0.00	0.03	0.00	0.00	0.00	0.00
FeO	0.05	0.00	0.00	0.07	0.10	0.07	0.15	0.04	0.10	0.03
MnO	0.04	0.00	0.04	0.00	0.01	0.04	0.02	0.02	0.04	0.01
MgO	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00
CaO	0.13	0.11	0.18	0.31	0.18	0.23	0.09	0.12	0.15	0.13
Na_2O	11.7	11.9	11.9	11.6	11.8	11.6	11.6	11.3	11.8	12.1
K_2O	0.04	0.03	0.01	0.04	0.03	0.01	0.03	0.06	0.06	0.02
Total	100.4	101.8	101.8	100.7	101.3	99.3	100.5	100.8	101.3	102.0
	Atomic ratios (O=8)									
Si	3.002	3.005	3.001	3.000	3.004	3.001	2.990	3.006	2.998	2.987
Ti	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000
Al	0.995	0.990	0.995	0.996	0.991	0.991	1.014	1.003	0.996	1.010
Cr	0.000	0.001	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
Fe^{2+}	0.002	0.000	0.000	0.003	0.004	0.003	0.005	0.001	0.004	0.001
Mn	0.001	0.000	0.001	0.000	0.000	0.001	0.001	0.001	0.001	0.000
Mg	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.001	0.000
Ca	0.006	0.005	0.008	0.014	0.008	0.011	0.004	0.006	0.007	0.006
Na	0.987	0.989	0.989	0.975	0.986	0.990	0.977	0.946	0.987	1.005
K	0.002	0.002	0.001	0.002	0.002	0.001	0.002	0.003	0.003	0.001
Total	4.995	4.994	4.996	4.991	4.995	4.998	4.993	4.967	4.998	5.011
XCa	0.006	0.005	0.008	0.015	0.008	0.011	0.004	0.006	0.007	0.006

Table 8 Chemical compositions of hematite.

Sample No.	YB108	YB108	YB120	ST2204	ST2204	ST2204	ST2204	ST2204
Rock type	BS	BS	QS	BS	BS	BS	BS	BS
Grain No.	5	4	4	7	7	7	8	8
Point No.	30	52	25	74	77	65#	72	71#
SiO_2	0.28	0.91	0.34	0.03	0.04	0.35	0.25	0.21
TiO_2	0.03	0.08	4.74	7.62	9.01	2.28	9.38	2.72
Al_2O_3	0.27	0.91	0.23	0.05	0.00	0.07	0.07	0.01
Cr_2O_3	0.00	0.02	0.00	0.06	0.05	0.00	0.09	0.03
FeO*	89.1	86.4	85.3	84.2	82.5	87.3	81.9	87.4
MnO	0.00	0.01	0.05	0.01	0.00	0.00	0.06	0.00
MgO	0.13	0.34	0.02	0.00	0.01	0.02	0.06	0.06
CaO	0.04	0.13	0.09	0.02	0.06	0.22	0.18	0.16
Total	89.9	88.8	90.8	92.0	91.7	90.2	92.0	90.6
Fe_2O_3	98.9	95.6	89.8	86.0	82.7	94.6	81.8	94.5
FeO	0.08	0.38	4.47	6.85	8.06	2.15	8.34	2.39
New total	99.7	98.4	99.7	100.6	99.9	99.7	100.2	100.1
Atomic ratios (O=3)								
Si	0.007	0.024	0.009	0.001	0.001	0.009	0.007	0.006
Ti	0.001	0.002	0.094	0.150	0.178	0.045	0.185	0.054
Al	0.008	0.029	0.007	0.002	0.000	0.002	0.002	0.000
Cr	0.000	0.000	0.000	0.001	0.001	0.000	0.002	0.001
Fe^{3+}	1.975	1.919	1.786	1.695	1.640	1.888	1.613	1.880
Fe^{2+}	0.002	0.008	0.099	0.150	0.177	0.048	0.183	0.053
Mn	0.000	0.000	0.001	0.000	0.000	0.000	0.001	0.000
Mg	0.005	0.014	0.001	0.000	0.000	0.001	0.002	0.002
Ca	0.001	0.004	0.003	0.001	0.002	0.006	0.005	0.005
Total	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000

Table 9 Chemical compositions of magnetite.

Sample No.	YB108	YB108
Rock type	BS	BS
Grain No.	5	5
Point No.	27	28
SiO_2	0.67	0.62
TiO_2	0.01	0.02
Al_2O_3	0.10	0.08
Cr_2O_3	0.00	0.03
FeO*	92.8	92.5
MnO	0.00	0.01
MgO	0.01	0.05
CaO	0.04	0.02
Total	93.6	93.3
Fe_2O_3	67.6	67.5
FeO	32.0	31.8
New total	100.4	100.1
Atomic ratios (O=4)		
Si	0.026	0.024
Ti	0.000	0.001
Al	0.005	0.004
Cr	0.000	0.001
Fe^{3+}	1.944	1.947
Fe^{2+}	1.024	1.020
Mn	0.000	0.000
Mg	0.001	0.003
Ca	0.002	0.001
Total	3.000	3.000

Table 10 Chemical compositions of stilpnomelane.

Sample No.	YB35	YB35
Rock type	BS	BS
Grain No.	2	2
Point No.	35	36
SiO_2	47.9	47.2
TiO_2	0.00	0.01
Al_2O_3	6.01	6.01
Cr_2O_3	0.04	0.00
FeO	27.1	26.9
MnO	1.25	1.39
MgO	7.28	7.01
CaO	0.52	0.56
Na_2O	0.15	0.10
K_2O	0.52	0.51
Total	90.8	89.7
Atomic ratios (Si=8)		
Si	8.000	8.000
Ti	0.000	0.001
Al	1.183	1.201
Cr	0.005	0.000
Fe^{2+}	3.785	3.813
Mn	0.177	0.200
Mg	1.813	1.771
Ca	0.093	0.102
Na	0.049	0.033
K	0.111	0.110
Total	15.215	15.230
XMg	0.324	0.317

資料・解説

四国中央部三波川帯猿田川地域より産する含赤鉄鉱片岩中の角閃石の化学組成

坂野靖行

要　旨

四国中央部三波川変成帯猿田川地域から産する含赤鉄鉱塩基性片岩及び石英片岩中の角閃石及び角閃石と共存する鉱物の EPMA 分析を行い，角閃石 221 点及びその他の鉱物（緑れん石・緑泥石・ざくろ石・白雲母・曹長石・赤鉄鉱・磁鉄鉱・スティルプノメレン）90 点の分析値を示した．分析が行われた試料は比較的高変成度である曹長石-黒雲母帯から採集された．これらの化学組成データは，三波川変成帯猿田川地域における後退変成作用を議論するために用いられた（Banno, 2000）．