

Note on rock-forming minerals (1)

Chemical compositions of Ca-amphibole in the late Tertiary volcanic rocks from the Joetsu district

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ABSTRACT

The volcanic and intrusive rocks of the Umikawa, Nanbayama and Yoneyama in late Pliocene are distributed in the northern part of Fossa Magna region, Niigata Prefecture. In the Umikawa pyroclastics, pyroxene and olivine basalts are common, and andesite is accompanied in subordinate amount. The majority of volcanic rocks from the Yoneyama are mainly two-pyroxene andesite and olivine basalt with small amounts of hornblende, clinopyroxene-orthopyroxene. The Nanbayama intrusive massif is composed of the porphyrite and porphyry. In these volcanic and intrusive rocks, amphibole occurs as phenocryst with opacitized rims. Hornblende gabbroic inclusions occur in calc-alkali andesites of the Yoneyama and Umikawa.

The amphiboles from the Yoneyama and Nanbayama are magnesiohornblende to pargasite, on the other hand, the amphibole in the Umikawa pyroclastics is pargasite. Amphiboles in the volcanic rocks in the present study are near the tremolite-pargasite join. When comparing the amphiboles from the three occurrences, K contents in amphibole from Umikawa pyroclastic rock are higher than those from the Nanbayama intrusive and Yoneyama volcanic rocks. K_2O contents of the bulk composition are the highest in the Yoneyama volcanic rocks. In this case, the amphibole is not affected with the bulk composition.

KEY WORDS

Ca-amphibole, Hornblende gabbro, Magnesiohornblende, Nanbayama, Pargasite, Yoneyama, Umikawa

Introduction

The intrusives of Pliocene age are distributed in the area from Yoneyama near Kashiwazaki-Choshi tectonic line in the northeastern part of Fossa Magna region to Umikawa near Itoigawa-Shizuoka tectonic line in the northwestern part of Fossa Magna region. The hornblende gabbros and xenocrysts are found in the volcanic rocks of the Umikawa and the Yoneyama in late Pliocene in the northern Fossa magna region. Many

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investigators reported that the hornblende gabbros occur in calc-alkali andesites of the Fossa magna region and the surrounding of the Japan sea (Aoki 1970, 1971; Yamasaki et al., 1966; Shimazu et al., 1979; Yagi and Takeshita, 1987). They suggested on the basis of coexisting clinopyroxene with high Al_2O_3 content that the hornblende gabbro derived by the lower crust and the upper mantle. We may estimate the physical conditions of pressure-temperature by Al_2O_3 content of amphibole. Oba (2000) reported that some hornblende gabbros are the cumulate rocks in the magma chamber. The chemical composition of amphiboles from the Umikawa and Nanbayama were not examined in detail yet. The aims of this paper are to further describe details of petrography and mineral chemistry.

Petrography of the volcanic and intrusive rocks of the Umikawa, Nanbayama and Yoneyama

Fig. 1 shows the localities of Pliocene volcanic rocks in the northern Fossa Magna region. Shimazu et al. (1979) reported that the Umikawa formations overlie late Miocene sediments and are composed mainly of calc-alkaline andesite lava and pyroclastics. Suzuki et al. (1985) demonstrated that the Umikawa andesite intercalated with thin layers of gray mudstone has four distinctive cyclic changes of lithology. The volcanic rocks of each early

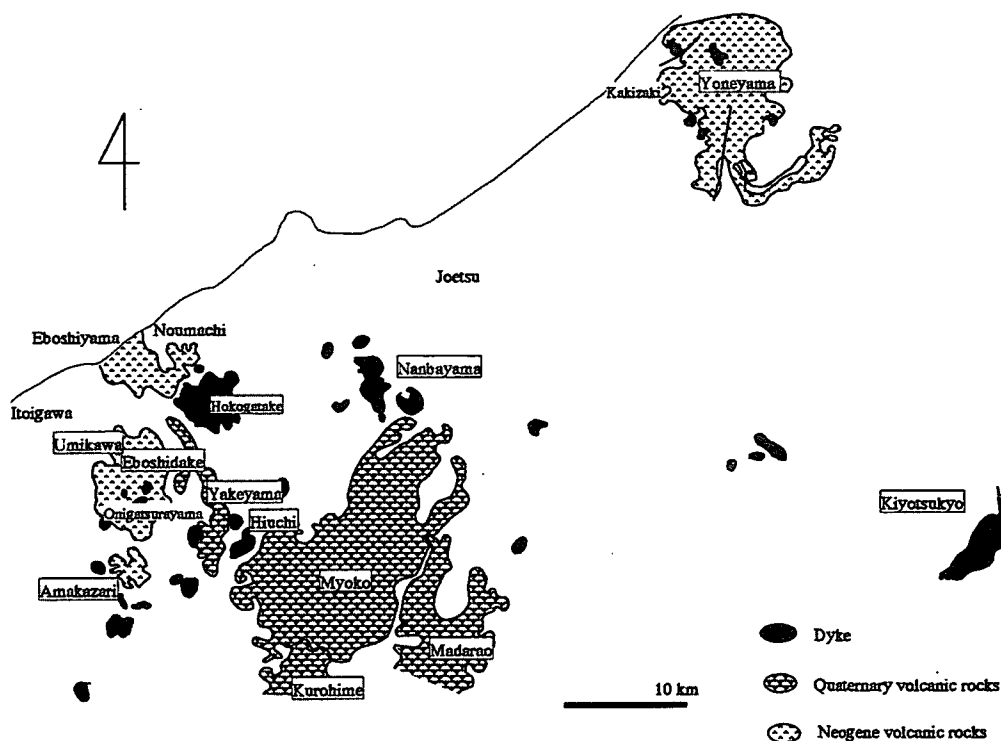


Figure 1 Distribution map of dykes, Quaternary and Neogene volcanic rocks of northern part of Fossa Magna.

to middle stage of each cycle unit are basalt and two- pyroxene andesite, whereas those of final stage of each cycle are hornblende- clinopyroxene-orthopyroxene andesite.

The Yoneyama formation is the Pliocene volcanic sequence composed of alternating beds of lava, pyroclastic and sedimentary rocks intruded by dykes (Sato et al., 1975; Kobayashi et al., 1989; Oba and Miyagawa, 1998). The majority of volcanic rocks are two-pyroxene andesite and olivine-clinopyroxene-orthopyroxene basalt with small amounts of hornblende-two pyroxene andesite.

Porphyrite and Porphyry distributed in Mt. Nanbayama in the suburbs of Joetsu city.

K-Ar age suggests that the intrusive stage of the Inoyama, which is satellite body of the Nanbayama, is older than that of the Nanbayama. The Inoyama intrusive rock is

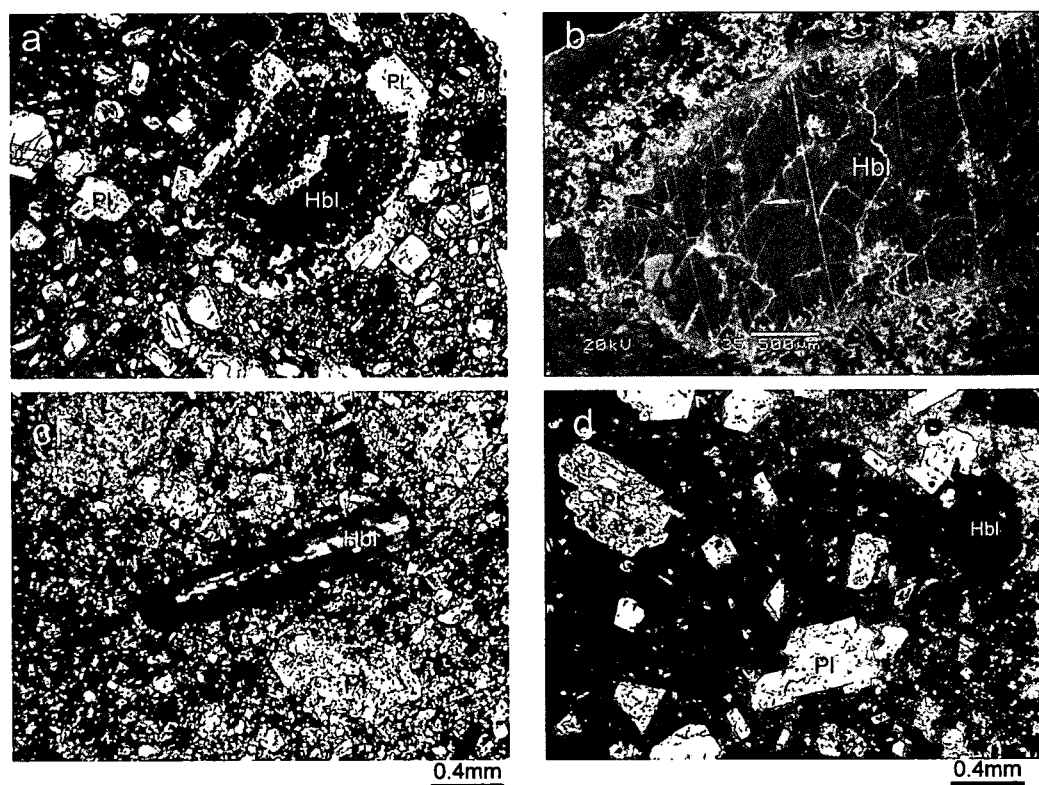


Figure 2 Photomicrographs of Ca-amphiboles in the volcanic and intrusive rocks from the Umikawa, Nanbayama and Yoneyama.

a: Red oxyhornblende with opacitized margin in the Umikawa pyroclastic rock.

b: Backscatter image of Red oxyhornblende with opacitized margin in the Umikawa pyroclastic rock.

c: Green hornblende with thin opacitized margin in porphyrite from the Nanbayama dyke.

d: Greenish brown hornblende with reaction rim in the lava from the Yoneyama. abbreviation: Hbl: hornblende, Pl: plagioclase.

hornblende-clinopyroxene-orthopyroxene porphyrite, on the other hand, that of the Nanbayama is clinopyroxene-hornblende porphyry. Amphibole is commonly observed as phenocryst in Nanbayama intrusive rocks. No hornblende is observed in the groundmass.

The color of hornblende is mostly brownish green and brown, sometimes brownish yellow or red. The brown and red hornblendes are surrounded by opacitized margin (Fig. 2a). The hornblende in the Umikawa is completely replaced by aggregate of a fine grained-crystals such as pyroxene and magnetite (Figs. 2a and 2b). Fig. 2b shows backscatter image of red oxyhornblende with opacitized margin. The hornblendes in porphyrite from the Nanbayama are slightly attack by opacitization (Fig. 2c). The hornblende in andesite from the Yoneyama has narrow opacitized rims (Fig. 2d).

Mineralogical data and discussion

The chemical compositions of minerals were analyzed with energy dispersive spectrometer (EDS, Link Isis 300) at the Joetsu University of Education. The selected spot analyses of amphibole at rim and core parts are given in Tables 1, 2 and 3 together with their structural formulae of 23 oxygens. Total Fe is expressed as FeO. Fe³⁺ content is not calculated.

According to the classification of Leake et al. (1997), the amphiboles from the Yoneyama and Nanbayama are magnesiohornblende to pargasite in Fig. 3. On the other hand, the amphiboles from the Umikawa were plotted in pargasite field (Fig. 3). Mg/(Mg+Fe) ratios of amphiboles are a constant from 7.2 to 6.4 of Si content and then increase with decreasing Si content in tetrahedra site. Mg/(Mg+Fe) ratios of amphiboles from the Nanbayama are higher than those of amphiboles from the Myoko volcanic group.

Amphiboles from these areas in the present study are plotted on and near the join tremolite-pargasite in Si versus Na+K in A site diagram (Fig. 4). The area bounded by a circle with dots indicates hornblendes in gabbroic inclusions from the Yoneyama reported by Shimazu et al. (1979). The circle area with lateral stripes is the cluster of amphiboles from the Myoko volcanic group reported by Oba (2000). These areas overlap each other. As compared to hornblende in gabbroic inclusions by Shimazu et al. (1979), amphiboles from the Umikawa, Nanbayama and Yoneyama in this study are plotted near the tremolite-pargasite join. It is known that the substitution of tschermakite increases with increasing pressure. The major variation in the chemical compositions of the amphiboles can be explained pargasite substitution in the tremolite formula. Most hornblende from the Umikawa, Nanbayama and Yoneyama is magnesiohornblende to pargasite with a small portion of tschermakite. Oba (2000) reported that Al₂O₃ content of coexisting clinopyroxene in the volcanic rocks from the Yoneyama is about 1~3 wt.%. Aoki (1971) concluded on the basis of the mineral assemblages of the mafic inclusions from Itinome-gata and the compositions of their minerals that the mafic inclusions recrystallized or crystallized in 600-110 and 6-9 kb. CaAl₂SiO₆ molecule in clinopyroxene is about 4.5~10.5 (Al₂O₃: 3.27~6.7

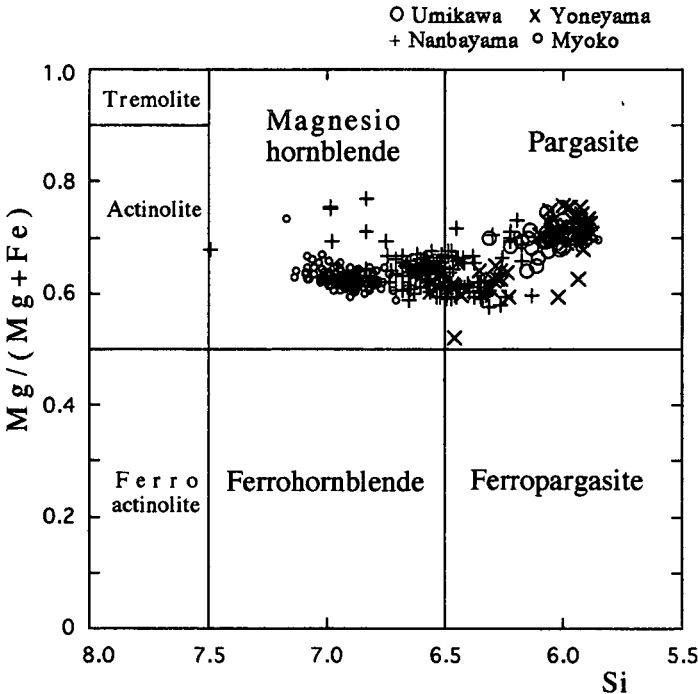


Figure 3 Classification of the calcic amphiboles from the Yoneyama volcanic rocks.

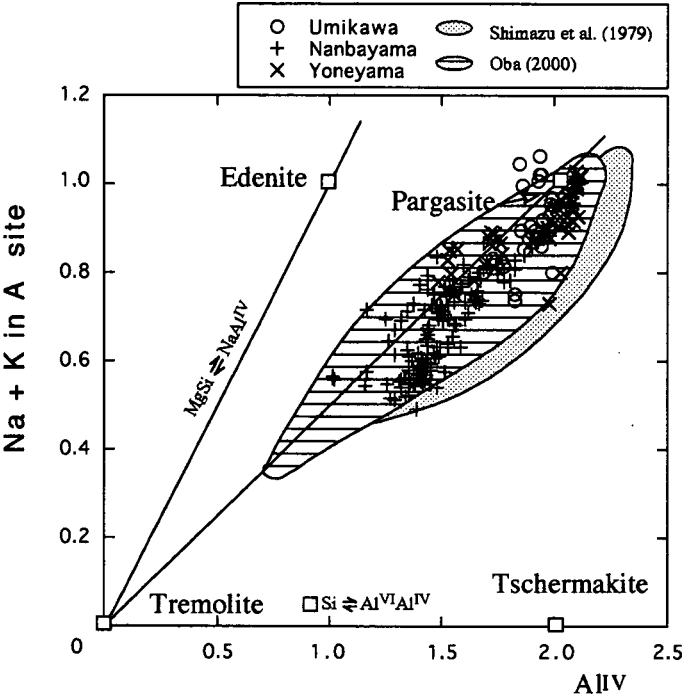


Figure 4 Plots of amphiboles in Al^{IV} versus $Na+K$ in A site diagram according Deer et al. (1963)

Table 2 The chemical compositions of amphiboles from the Nanbayma intrusive rocks

	Dou-7	11	150	153	Sum-13	27	204	206	Yach-16	32	43	54	Nak-1	3	179	181
	core	rim	core	rim	core	rim	core	rim	core	rim	core	rim	core	rim	core	rim
SiO ₂	42.34	40.85	42.06	41.96	45.07	44.98	43.80	43.04	44.64	44.69	44.45	45.62	44.04	47.96	47.25	44.28
TiO ₂	1.76	1.84	1.88	1.59	0.82	1.17	1.21	1.55	2.50	2.33	2.47	2.24	2.21	1.39	1.29	2.14
Al ₂ O ₃	11.51	13.82	11.87	12.05	9.68	11.75	10.27	10.89	10.18	10.34	10.71	10.06	9.78	6.55	6.24	10.03
Cr ₂ O ₃	0.03	0.04	0.00	0.00	0.00	0.01	0.01	0.00	0.07	0.07	0.03	0.00	0.00	0.00	0.03	0.02
FeO	13.98	11.11	14.73	14.82	14.21	14.48	14.02	12.39	12.72	13.97	13.29	13.68	14.22	10.07	10.05	14.45
MnO	0.27	0.17	0.63	0.79	0.85	0.70	0.67	0.69	0.29	0.33	0.30	0.35	0.41	0.37	0.30	0.44
MgO	12.87	14.82	12.40	12.28	12.94	11.63	13.14	13.71	13.60	13.12	13.66	13.75	13.86	17.09	17.20	13.97
CaO	11.65	11.81	11.17	10.61	10.69	9.49	10.83	10.88	10.91	10.62	10.79	10.77	10.88	11.74	11.46	10.89
Na ₂ O	1.86	2.14	1.90	2.16	2.05	2.53	2.47	2.78	1.85	1.96	2.01	1.85	2.05	1.59	1.56	2.07
K ₂ O	0.47	0.59	0.40	0.45	0.32	0.76	0.42	0.42	0.46	0.42	0.43	0.39	0.47	0.37	0.19	0.44
Total	96.74	97.19	97.04	96.71	96.63	97.50	96.84	96.35	97.22	97.85	98.14	98.71	97.92	97.13	95.57	98.73
Structural formulae calculated on the basis of 23 oxygens																
Si	6.356	6.047	6.317	6.326	6.738	6.654	6.561	6.450	6.587	6.583	6.515	6.640	6.520	6.983	6.988	6.504
AlIV	1.644	1.953	1.683	1.674	1.262	1.346	1.439	1.550	1.413	1.417	1.485	1.360	1.480	1.017	1.012	1.496
AlVI	0.393	0.458	0.418	0.468	0.444	0.702	0.374	0.373	0.358	0.379	0.366	0.366	0.227	0.108	0.075	0.240
Cr	0.004	0.005	0.000	0.000	0.000	0.001	0.001	0.000	0.008	0.008	0.003	0.000	0.000	0.000	0.003	0.002
Ti	0.199	0.205	0.212	0.180	0.092	0.130	0.136	0.175	0.277	0.258	0.272	0.245	0.246	0.152	0.143	0.236
Fe ²⁺	1.755	1.375	1.850	1.869	1.777	1.791	1.756	1.553	1.570	1.721	1.629	1.665	1.761	1.226	1.243	1.775
Mn	0.034	0.021	0.080	0.101	0.108	0.088	0.085	0.088	0.036	0.041	0.037	0.043	0.051	0.046	0.038	0.055
Mg	2.880	3.270	2.776	2.760	2.884	2.564	2.934	3.062	2.991	2.881	2.984	2.983	3.059	3.709	3.791	3.059
Ca	1.844	1.844	1.769	1.687	1.685	1.480	1.711	1.719	1.698	1.650	1.668	1.653	1.699	1.803	1.787	1.687
Na	0.541	0.614	0.553	0.631	0.594	0.726	0.717	0.808	0.529	0.560	0.571	0.522	0.588	0.449	0.447	0.590
K	0.090	0.111	0.077	0.087	0.061	0.143	0.080	0.080	0.087	0.079	0.080	0.072	0.089	0.069	0.036	0.082
A	0.741	0.903	0.735	0.782	0.644	0.626	0.795	0.858	0.554	0.576	0.611	0.549	0.719	0.561	0.565	0.726
Mg/(Mg+Fe)	0.621	0.704	0.600	0.596	0.619	0.589	0.626	0.664	0.656	0.626	0.647	0.642	0.635	0.752	0.753	0.633
Ca	0.285	0.284	0.277	0.267	0.266	0.254	0.267	0.271	0.271	0.264	0.266	0.262	0.261	0.268	0.262	0.259
Mg	0.444	0.504	0.434	0.437	0.454	0.439	0.458	0.483	0.478	0.461	0.475	0.473	0.469	0.550	0.556	0.469
Fe	0.271	0.212	0.289	0.296	0.280	0.307	0.274	0.245	0.251	0.275	0.259	0.264	0.270	0.182	0.182	0.272

Table 3 The chemical compositions of amphiboles from the Yoneyama volcanic rocks

	H-401	409	420	421	431	444	Yo-36	43	48	S-49	83	87	234	253	257	262
	rim	core	rim	rim	core	rim	rim	core	core	rim	core	rim	rim	rim	core	rim
SiO ₂	39.95	43.67	41.33	40.41	40.03	40.68	43	43.44	42.87	43.4	40.3	39.94	42.9	40.65	40.1	39.9
TiO ₂	1.89	1.24	1.72	1.85	1.8	1.83	1.96	2.06	2.41	2.03	1.83	1.83	1.83	1.83	1.83	1.83
Al ₂ O ₃	15.68	17.13	15.44	14.92	15.34	15.06	11.86	12.48	12.75	12.44	15.11	15.65	7.99	14.28	15.96	14.95
Cr ₂ O ₃	0.06	0	0	0.16	0.11	0.08	0.16	0.11	0.12	0.11	0.01	0	0	0	0	0.01
FeO	10.26	9.87	10.45	9.45	10.11	9.56	14.51	13.85	15.11	14.72	10.64	9.75	17.82	10.09	9.57	10.1
MnO	0.06	0.13	0.05	0.04	0.05	0	0.25	0.24	0.36	0.37	0.15	0.07	0.34	0.07	0	0.13
MgO	13.99	16.56	14.65	14.9	14.51	14.83	13.48	13.91	12.46	12.78	14.03	13.62	10.92	14.62	13.57	14.74
CaO	10.88	9.35	11.1	12.11	12.23	12.28	11.14	11.19	11.08	11.21	12.6	12.57	16.54	12.5	11.82	12.66
Na ₂ O	1.93	2.61	1.98	2.05	1.97	2	2.2	2.41	2.26	2.16	1.89	1.78	1.16	1.91	1.54	1.86
K ₂ O	1.78	1.35	1.82	1.72	1.71	1.61	1.18	1.12	1.26	1.21	1.24	1.53	0.03	1.44	1.65	1.36
Total	96.48	101.9	98.54	97.61	97.86	97.93	99.74	100.8	100.7	100.4	97.8	96.74	99.53	97.39	96.04	97.54
Structural formulae calculated on the basis of 23 oxygens																
Si	5.947	6.058	6.018	5.952	5.9	5.965	6.292	6.262	6.231	6.304	5.945	5.935	6.46	6.011	5.973	5.9
AlIV	2.053	1.942	1.982	2.048	2.1	2.035	1.708	1.738	1.769	1.696	2.055	2.065	1.54	1.989	2.027	2.1
AlVI	0.699	0.859	0.668	0.541	0.565	0.568	0.338	0.383	0.415	0.434	0.571	0.676	0.121	0.5	0.775	0.505
Al	2.751	2.801	2.65	2.59	2.665	2.603	2.045	2.12	2.184	2.13	2.627	2.741	1.418	2.489	2.802	2.605
Cr	0.007	0	0	0.018	0.013	0.009	0.018	0.012	0.014	0.012	0.001	0	0	0	0	0.001
Ti	0.212	0.129	0.188	0.205	0.2	0.202	0.216	0.223	0.263	0.222	0.203	0.205	0.207	0.204	0.205	0.203
Fe ²⁺	1.277	1.145	1.273	1.164	1.246	1.172	1.776	1.67	1.837	1.788	1.313	1.212	2.244	1.248	1.192	1.249
Mn	0.008	0.015	0.006	0.005	0.006	0	0.031	0.029	0.044	0.046	0.019	0.009	0.043	0.009	0	0.016
Mg	3.104	3.424	3.18	3.271	3.188	3.241	2.94	2.989	2.699	2.767	3.085	3.017	2.451	3.222	3.013	3.249
Ca	1.708	1.368	1.704	1.881	1.901	1.899	1.719	1.701	1.698	1.717	1.96	1.97	2.627	1.949	1.857	1.974
Na	0.557	0.702	0.559	0.585	0.563	0.569	0.624	0.674	0.637	0.608	0.541	0.513	0.339	0.548	0.445	0.533
K	0.338	0.239	0.338	0.323	0.322	0.301	0.22	0.206	0.234	0.224	0.233	0.29	0.006	0.272	0.314	0.257
A	0.91	0.882	0.917	0.994	1.004	0.962	0.882	0.888	0.842	0.819	0.925	0.891	0.796	0.951	0.8	0.988
Mg/(Mg+Fe)	0.708	0.749	0.714	0.738	0.719	0.734	0.623	0.642	0.595	0.607	0.702	0.713	0.522	0.721	0.716	0.722
Ca	0.28	0.230	0.277	0.298	0.300	0.301	0.267	0.267	0.272	0.274	0.308	0.318	0.359	0.304	0.306	0.305
Mg	0.51	0.577	0.516	0.518	0.503	0.513	0.457	0.470	0.433	0.441	0.485	0.487	0.335	0.502	0.497	0.502
Fe	0.21	0.193	0.207	0.184	0.197	0.186	0.276	0.263	0.295	0.285	0.206	0.195	0.307	0.194	0.197	0.193

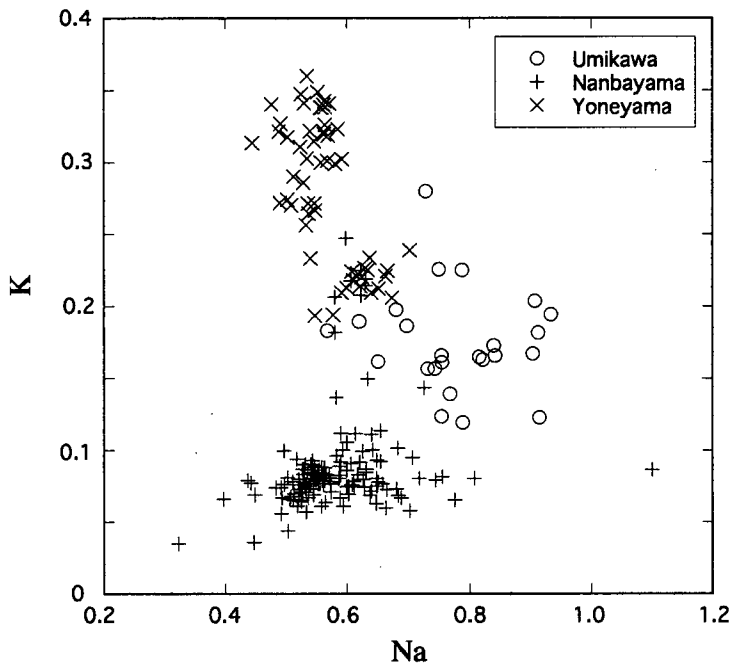


Figure 5 Plots of amphiboles in Na versus K diagram

wt.%). Shimazu et al. (1979) reported that Al_2O_3 content of clinopyroxene in hornblende gabbros is about 2~8 wt.%. Oba (2000) determined on the basis of Al_2O_3 content of clinopyroxene that some hornblende gabbros may be the cumulate rocks in the magma chamber. After hornblende phenocryst cumulated in magma chamber, the cumulate inclusions are carried by new magma derived from the lower crust.

When comparing the amphiboles from the three occurrences, K contents in amphibole from Umikawa pyroclastic rock are higher than those from the Nanbayama intrusive and Yoneyama volcanic rocks, as shown in Fig. 5. Oba (1990) reported that the composition of amphibole becomes rich in pargasite with increasing temperature. In addition, the composition of amphibole is affected with the bulk composition. However, K_2O contents of the bulk composition of the Umikawa pyroclastic rock are lower than those of the Yoneyama volcanic rock. Temperature, estimated by clinopyroxene-orthopyroxene geothermometer, of crystallization of amphibole from both Yoneyama and Umikawa are almost similar. The difference of K content in amphibole may be depended on pressure condition of crystallization.

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