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Petrology of Igneous Rocks in Admiralty Bay, King George Island (South Shetland Islands, Antarctica)

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남극 킹죠지섬 어드미럴티만 일대와 펭귄섬에 분포하는 화성암류에 대한 암석학적 연구

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The volcanic rocks distributed in Admiralty Bay and Penguin Island are divided into four formations: 1) pyroxene basalt of Fildes Formation (FF), 2) basaltic andesite, two-pyroxene andesite and augite andesite of Hennequin Formation (HF), 3) pyroxence gabbro of Lions Rump Formation (LRF), and 4) olivine basalt of Penguin Formation (PF). Each formation shows specific chemical affinity: that is, tholeiitic affinity of FF, calc-alkaline one of HF and alkaline one of PF. The abundance patterns of trace elements show that the volcanic rocks were originated from the magmas generated by partial melting of upper mantle in island-arc environment, but the chemical feature of trace elements in PF is thought to be the consequence of mixing of island-arc type alkaline magma with within-plate (or back-arc) tholeiitic one. The transition of chemical properties from tholeiitic affinity of FF to alkaline one PF can be explained by the change of subduction mode with time. The generation of PF magma having alkaline affinity is thought to have related to the opening of Bransfield Strait during late Tertiary as well as the overall change of subduction mode around South Shetland Islands.

Key words: King George Island, arc environment, magma series

남극 킹죠지섬의 어드미럴티만 일대와 펭귄섬에 분포하는 화성암류는 다음과 같은 4개의 층으로 나뉘어진다: 1) 필데스층(휘석 현무암), 2) 헤네퀸층(현무암질 안산암, 양휘석 안산암, 오자이트 안산암), 3) 라이온즈 럼프층(휘석반려암), 4) 펭귄층(감람석 현무암). 라이온즈 럼프층을 제외한 화산암류들의 전반적인 주성분 원소의 화학조성은 필데스층이 tholeiite계열, 헤네퀸층이 calc-alkaline계열 그리고 펭귄층이 alkaline계열의 특성을 보인다. 미량원소의 화학조성은 모든 화산암류들이 도호 환경하의 맨틀로부터 유래되었다는 것을 보여주지만, 펭귄층 현무암류의 미량원소 조성은 도호기원의 alkaline 마그마와 판내부(또는 배호) 기원의 tholeiite 마그마와의 혼합의 결과로 설명되어진다. 결국 이러한 화학조성의 변화는 시간에 따른 subduction양식의 변화를 반영한다고 생각되는데, 특히 alkaline 계열의 조성을 보이는 펭귄층의 현무암은 신생대말부터 시작한 브랜스필드 해협의 확장과 관련되어 형성된 것으로 보인다.

주요어: 킹죠지섬, 도호환경, 마그마계열

INTRODUCTION

South Shetland Islands (SSI) is located about 100 km north-east from the Antarctic Peninsular. The SSI forms a Jurassic-Quaternary magmatic island-arc on the sialic basement of metasedimentary rocks. The volcanism had gradually moved northeastward with time along the arc (Tarney et al., 1982; Smellie et al., 1984; Jwa, 1992). King george Island (KGI) is located in the northeastern part of the SSI. KGI is Cretaceous-Tertiary magmatic island-arc characterized by the intrusion and the eruption of magmas having intermediate compositions between island-arc tholeiitic and calc-alkaline natures (Birkenmajer, 1985; Barbieri et al., 1989). Alkali olivine basalts within the Bransfield Strait (the islands of Deception and Bridgeman) and along the southern margin of KGI (Penguin island, Turret and Three Sisters Point) are thought to have erupted during the extensional period of the Bransfield Strait initiated by the change of subduction mode around the SSI (Hawkes, 1961; Weaver et al., 1979; Jwa and Kim, 1991). The volcanic rocks around KGI show wide variations in composition, presumably related with the change of subduction mode with time. In this study, petrological and geochemical characteristics of the rocks occurring in the Admiralty Bay of KGI and Penguin island are carefully examined. On the basis of these results, petrogenetic environments for the igneous rocks are also inferred.

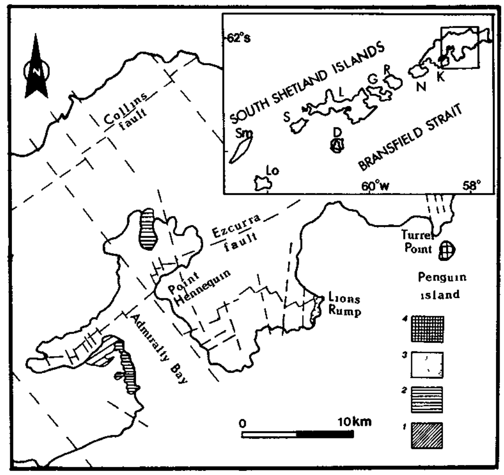

Fig. 1. Simplified geological map of King George Island (after Smellie et al., 1984; Birkenmajer, 1983). 1, Fildes Formation; 2, Hennequin Formation; 3, Lions Rump Formation; 4, Penguin Formation; Dotted lines indicate inferred faults; K=King George island, N=Nelson island, R-Robert island, G=Greenwich island, L=Livingston island, D-Deception island; S=Snow island, Sm=Smith island, Lo=Low island.

LITHOSTRATIGRAPHY

The lithostratigraphy of KGI can be divided into two formaions: lower Fildes formation which is mainly distributed to the western part of the Admiralty Bay and consists of basaltic rocks, and upper Hennequin formation which to the eastern part and of andesitic rocks. The ages of Fildes and Hennequin formations are Paleocene-Eocene and Eocene-Oligocene, respectively (Smellie et al., 1984). It is thus thought that the volcanism of KGI was shifted northeastward with time. Based on the Collins and Ezcurra strike-slip faults resulted from anticlockwise rotation of the Antarctic continent relative to the SSI microcontinent, it can be divided into four blocks: upthrown Barton Horst block which makes up the axial part of the KGI, downthrown Fildes block and Warzawa & Kracow block situated in north and south of Barton block respectively and Penguin island group (Birkenmajer, 1983). In the present study, from the lithological and geochemical characteristics, the igneous rocks can be divided into four formations: Fildes Formation (FF), Hennequin Formation (HF), Lions Rump Formation (LRF) and Penguin Formation (PF) (Fig. 1). LRF of lower Tertiary (Smellie et al, 1984) belongs to the Kracow block and PF of Quaternary (Smellie et al., 1984) to the Penguin island group by the division of Birkenmajer (1983).

PETROGRAPHY

Most of volcanic rocks in FF, HF and PF show porphyritic textures, commonly with very fine-grained groundmass. The volcanic rocks are classified partly based on mineral assemblage of phenocrysts and partly on the nomenclature of Ewart (1979), using major elements data. The mode data for the volcanic rocks of each formation are presented in Table 1.

Table 1. Modal compositions of the rocks.

	Ol	Cpx	Opx	Amp	Bt	Pl	Qtz	Ore	Vac	Sph	Matrix	Glass	C.I.
P-1	11.9[6]	3.5				8.0		0.2	20.4		55.7		15.6
P-2	8.9	3.4[7]				7.7		0.1	25.0		30.7	23.7	12.4
P-3	7.1[6,7]	8.2[7]				18.0			7.8		58.6		15.3
P-4	8.9	6.2[7]	0.1[7]			15.8			2.2		66.5		14.7
P-5	12.8[6]	2.8[6.9]				8.3		0.3[2]	21.5		54.2		15.9
P-6		3.7		16.7[1]		73.2[2]	1.4	4.3		0.7			25.4
P-9						73.9[2,4]	23.8	2.3					18.0
P-10						91.5[1,2,4]	5.3	3.0					39.2
19-1		3.6[1,3,4,7,8]				46.2[1,4]		1.4			48.6[1,4]		5.0
19-4		4.5[4,7]				43.0[1]					52.3[1,4,7]		4.5
19-5		1.2[4,7,8]				1.3[4]	1.6				95.8[4]		1.2
19-6		5.8[1,4,7]				44.4[1,4]		0.1	0.1		49.6[1,4]		5.9
18-3		12.0[3,4,7]				53.6[4]		0.1			34.1[4]		12.1
LR-1		24.9[4,7]				70.3[1]	0.8	5.3					30.2
LR-2		17.2	0.2			80.4[1,4]		3.0					13.4
20-1		4.2[1,7,4]	2.1[1,7,4]			35.5[1,7,4]		0.9			41.7[1,4]	15.5	6.2
20-4		9.2[4,7]	1.2[4,7]			36.5		0.5	4.4*[4,5,8]		47.8[1,4]		15.3
20-2		11.2[7]				32.2		0.6			53.7	2.0	11.8
22-1		1.9	0.2[1]		0.5	9.4[1,7]		0.3			87.7[1,3]		2.0
22-2		1.5[1,3,7]				13.4[2]		0.8			83.7[2,3]		2.3
20-3		1.0[1]				4.8[1,8]		1.8	27[1,7,8,4]			64.8	2.8

Abbreviation; Ol: olivine, Cpx: clino-pyroxene, Opx: ortho-pyroxene, Amp: amphibole, Bt: biotite, Pl: plagioclase, Qtz: quartz, Vac: vacuole, Sph: sphene, C.I.: color index. Small size number indicates secondary mineral: 1. chlorite, 2. sericite, 3. calcite, 4. epidote, 5. quartz, 6. serpentine, 7. leucoxene, 8. chalcedony. *: amygdaloidal texture. Penguin formation: p-1, p-2, p-3, p-4, p-5, p-6, p-9, p-10, Fildes formation: 19-1, 19-4, 19-5, 19-6, 18-3, Lions Rump formation: LR-1, LR-2, Hennequin formation: 20-1, 20-2, 20-3, 20-4, 22-2.

Fildes Formation (FF)

This formation consists of pyroxene baslats (Sample No. 19-1, 19-4, 19-5, 19-6, 18-3) showing hypocrystalline and glomeroporphyritic texture. The phenocrysts are composed of plagioclase, clinopyroxene including subordinate amounts of opaque minerals. Euhedral plagioclase phenocrysts include dusty zone of opaque mineral and clinopyroxene. Clinopyroxene phenocrysts usually show hour glass zoning and some of them have corroded boundary. The groundmass consists of tabular plagioclase, granular opaque mineral and clinopyroxene with variable amounts of glass materials in each sample.

Hennequin Formation (HF)

This formation consists of basaltic andesite (Sample No. 20-2), hypersthene augite andesite (Sample No. 20-1, 20-4, 22-1) and augite andesite (Sample No. 22-2, 20-3). The rocks also show glomeroporphyritic and fluidal texture. The phenocrysts are composed of plagioclase, clinopyroxene and orthopyroxene. Euhedral plagioclase phenocrysts show strong normal zoning and some of them have dusty rims of fine-grained opaque minerals. Clinopyroxene and orthopyroxene phenocrysts usually contain opaque mineral inclusions. Some of orthopyroxene phenocrysts have chemically zoned narrow rim. The groundmass contains plagioclase microlite, granular clinopyroxene, dots of opaque mineral and brownish glass (20-1, 20-4, 20-3). Sample No. 20-4 has vesicles (up to 4%) filled with chalcedony, epidote and chlorite.

Lions Rump Formation (LRF)

This formation is represented by pyroxene gabbros (Sample No. LR-1, LR-2) composed of plagioclase, clinopyroxene and opaque mineral with minor amounts of orthopyroxene. Euhedral to subhedral plagioclase occasionally have dusty zone of opaque minerals. Subhedral to anhedral clinopyroxenes usually contain opaque mineral inclusions and show hour glass zoning.

Penguin Formation (PF)

This formation is predominated by olivine basalts (Sample No. p-1, p-2, p-3, p-4, p-5) having vitro-porphyritic texture and a number of vesicles. The phenocrysts are olivine, plagioclase, clinopyroxene, and orthopyroxene with minor amounts of fine-grained opaque minerals. Olivine phenocrysts show euhedral shape and have no reaction rim with pyroxene. They are severely corroded by groundmass. Plagioclase phenocrysts have a concentric dusty zone occupied by mafic and opaque minerals. Clinopyroxene phenocrysts show hour glass zoning and are slightly corroded by groundmass. The groundmass is composed of tabular plagioclase, granular olivine, clinopyroxene and dots of opaque minerals. It often shows fluidal texture.

GEOCHEMISTRY

The 14 samples of volcanic rocks (FF, HF and PF) and 2 samples of gabbros (LRF), which are least altered without amygdaloidal texture, were selected for geochemical investigation. The chemical analysis was carried out at the University of London, using XRF and ICP-AES(Walsh, 1980). The composition of major oxides and amounts of trace elements are presented in Table 2.

In order to examine the fractionation effects, FeO*/MgO ratio is used as a differentiation index in this study, which is thought to be suitable for the consideration of fractionation effect of early crystallizing minerals such as olivine, orthopyroxene and clinopyroxene. The variations of major elements are shown in Fig. 2. The FeO*/MgO ratios in three volcanic formations increase in order of PF, FF and HF. If the source materials were the same, the degree of fractionation of olivine and pyroxene would increase to the same order. But, this is not the case because the source materials are thought to have been different for Penguin formation, as described later.

TiO_2 contents of PF are relatively abundant. TiO_2 contents of FF and HF progressively increase with increasing FeO*/MgO ratio, which means that Ti-bearing minerals (ilmenite and/or rutile) have not crystallized yet. CaO contents show negative correlation with FeO*/MgO ratio except for PF, which suggests fractionation of Ca-plagioclase. CaO and Al_2O_3 contents of HF are more depleted than those of FF, under similar FeO*/MgO ratio. Thus, the magma producing HF have fractionated more Ca-plagioclase rather than FF, assuming the same or similar source materials. Na_2O, K_2O and P_2O_5 contents show positive correlation with FeO*/MgO ratio, which means that Na-plagioclase, K-feldspar and apatite have not been fractionated yet.

The variations of trace elements against FeO*/MgO are presented in Fig. 3. Cr, Ni and Co contents show negative correlations with FeO*/MgO ratio. These trends indicate the fractionation of Mg-rich olivine preferentially takes those elements. The steep gradient of PF means that PF magma has been strongly fractionating olivine, while the other magmas has completed fractionation of olivine.

Table 2. Chemical compositions of major and trace elements.

	Penguin Formation					Fildes formation				Hennequin formation					Lions-Rump Formation	
Sample No.	P-1	P-2	P-3	P-4	P-5	19-1	19-4	19-6	18-3	20-1	20-2	20-4	22-1	22-2	LR-1	LR-2
Major oxide (wt%)																
SiO_2	49.31	47.93	49.2	49.31	47.56	50.23	49.09	50.23	48.93	56.24	55.66	54.05	58.77	57.18	52.57	49.41
Al_2O_3	15.38	15.96	17.10	17.14	15.71	20.99	20.33	20.81	19.85	17.70	17.37	17.96	18.10	16.66	18.17	18.45
Fe_2O_3*	9.87	9.78	9.85	9.70	9.68	8.48	8.99	9.26	9.07	7.69	8.3	8.55	8.02	6.98	8.35	9.12
MgO	11.48	10.48	8.93	8.33	10.51	3.45	4.55	4.17	5.43	3.38	4.17	4.12	2.69	2.42	5.80	6.76
CaO	9.36	9.7	10.11	9.87	9.62	9.97	10.53	10.13	10.28	6.67	7.93	7.71	6.56	7.80	8.86	9.16
Na_2O	3.16	3.38	3.73	3.76	3.38	3.61	3.47	3.68	2.99	3.93	3.36	3.35	4.3	3.68	3.32	3.43
K_2O	0.56	0.64	0.68	0.68	0.62	0.73	0.47	0.56	0.50	2.06	0.86	1.27	2.19	0.74	0.80	0.65
TiO_2	1.11	1.20	1.25	1.25	1.16	0.75	0.76	0.78	0.72	0.79	0.80	0.80	0.99	0.92	0.80	0.78
P_2O_5	0.25	0.28	0.29	0.30	0.28	0.21	0.19	0.19	0.19	0.26	0.29	0.24	0.44	0.42	0.20	0.20
MnO	0.16	0.15	0.16	0.15	0.15	0.16	0.19	0.16	0.15	0.15	0.13	0.12	0.18	0.16	0.21	0.17
Total	100.64	99.5	101.3	100.49	98.67	98.58	98.57	99.97	99.37	98.11	98.87	98.17	102.24	96.96	99.08	98.13
Trace element (ppm)																
Ba	160	165	177	175	159	221	155	163	155	364	300	295	508	546	217	172
Co	42	39	35	34	39	25	27	27	31	21	24	25	16	15	26	29
Cr	267	256	220	189	281	30	37	35	35	24	44	36	12	15	101	110
Cu	116	102	131	122	119	106	154	144	146	172	104	145	113	47	63	57
Li	3	4	5	6	4	8	4	6	11	14	5	8	10	16	63	57
Nb	6	6	6	6	6	3	3	3	3	5	4	5	6	5	4	3
Sc	29	29	29	27	29	25	33	29	3	22	25	27	25	22	27	29
Sr	537	566	629	633	545	671	605	628	609	563	663	626	639	684	404	417
V	260	272	281	286	264	260	284	282	277	203	218	228	175	153	218	231
Y	17	17	17	17	17	17	17	17	15	25	25	23	36	32	25	19
Zn	73	76	77	77	74	78	78	79	75	79	77	79	90	86	76	80
Zr	63	67	67	68	66	61	78	53	48	160	164	136	151	133	80	48
Rb	6	7	5	8	6	9	<5	7	5	41	20	11	34	9	15	12

*: total Fe as Fe_2O_3

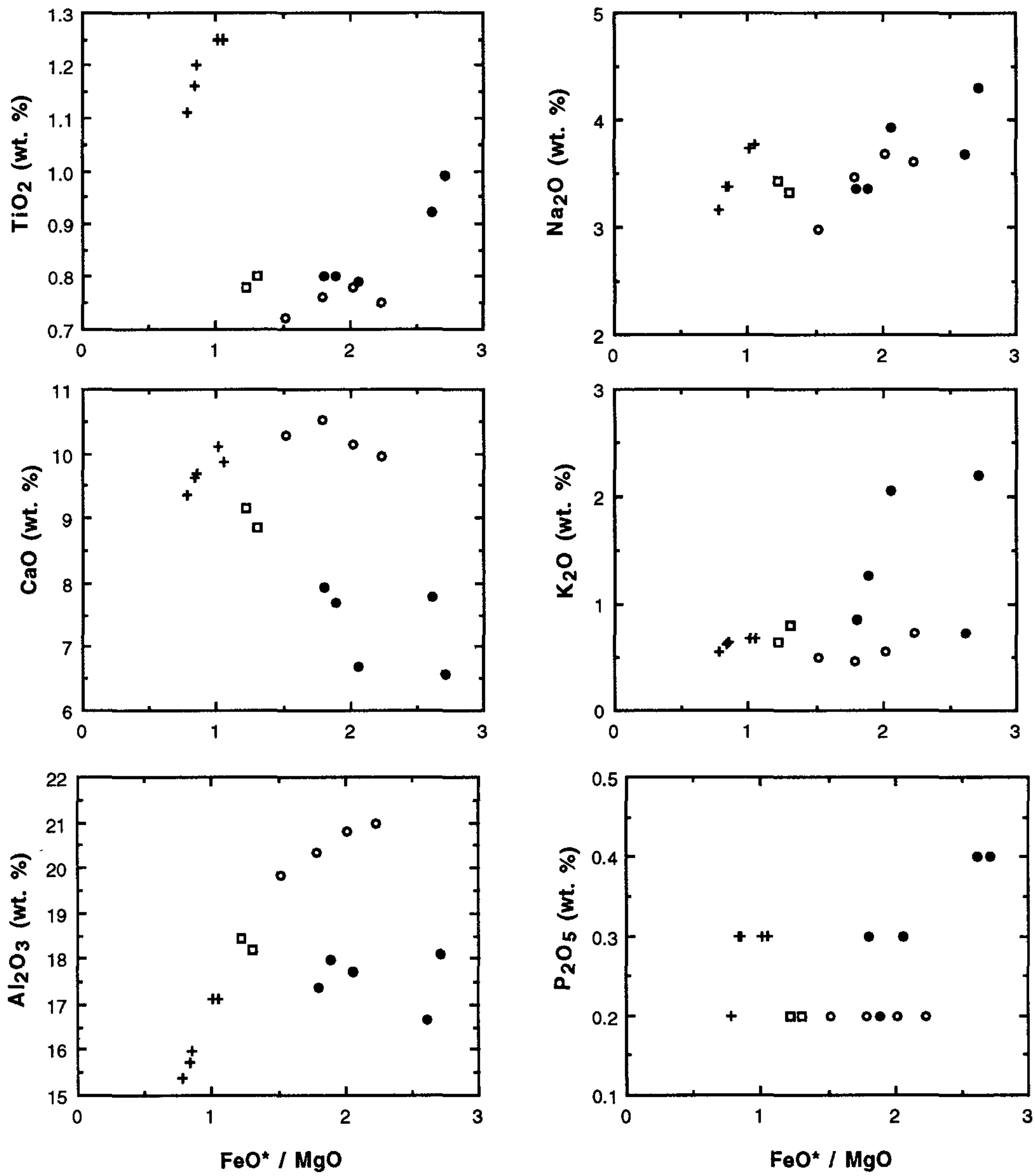

Fig. 2. Major oxides vs. FeO*/MgO variation diagrams. Symbols: open circle, Fildes Formation; closed circle, Hennequin formation; square, Lions Rump Formation; cross, Penguin Formation.

Y, Rb, Ba, Sr and Nb contents roughly show positive correlations with FeO*/MgO ratio. These elements had not been differentiated in the early fractionating minerals such as olivine, clinopyroxene and orthopyroxene and were preferentially concentrated in liquid phase during mafic silicate crystallization. The overall variation trends of trace elements except for Nb contents represent that all of the rocks in the study area have experienced similar crystal fractionation processes regardless of the difference of source compositions.

But Nb contents of PF show dissimilar trend. As Nb in subduction zone is highly immobile, its abundance in basaltic rocks has been need as an useful indicator for the source materials (McCulloch and Gamble, 1991). Thus, the differ-

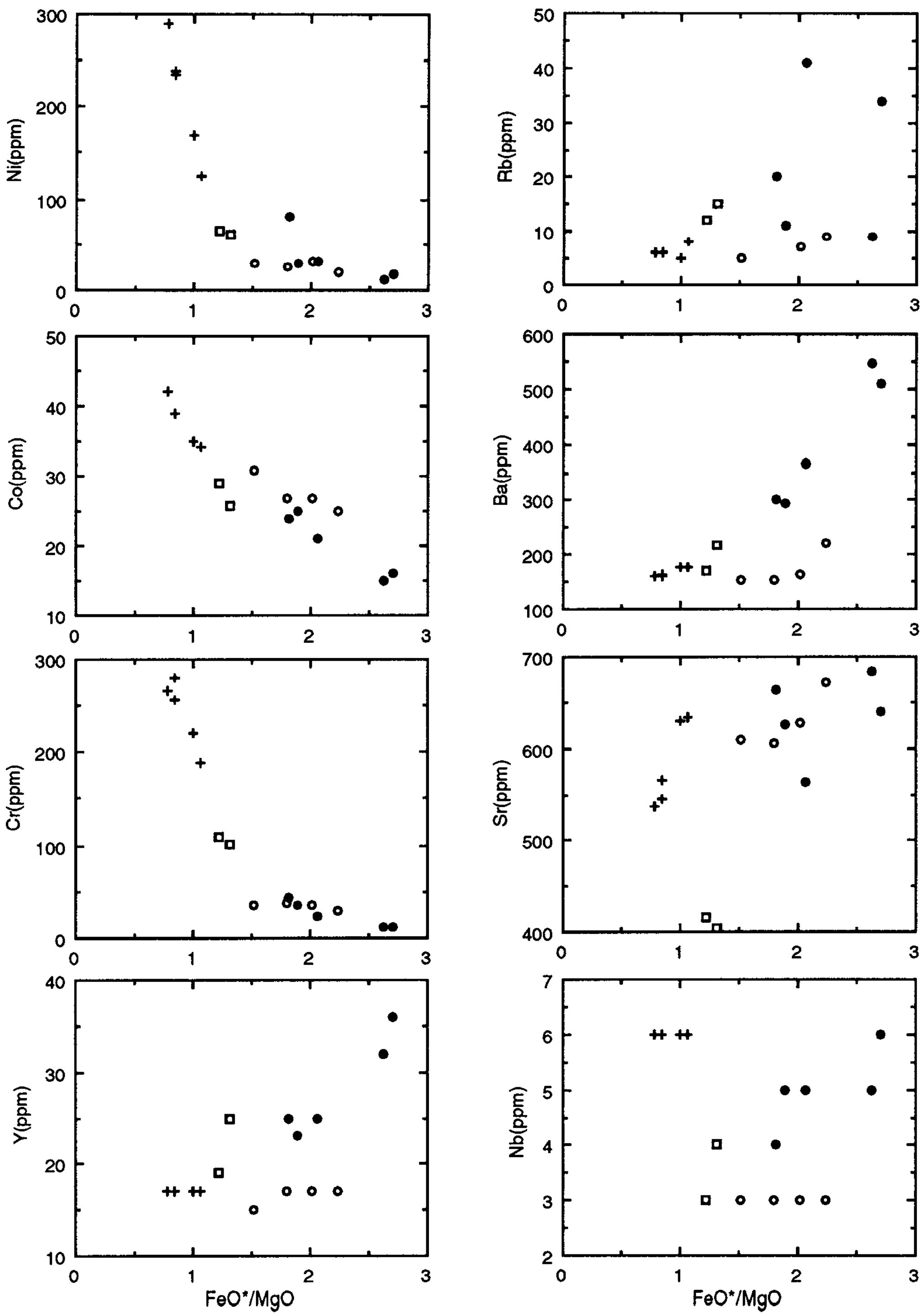

Fig. 3. Trace elements vs. FeO*/MgO variation diagrams. Symbols are the same as Fig. 2.

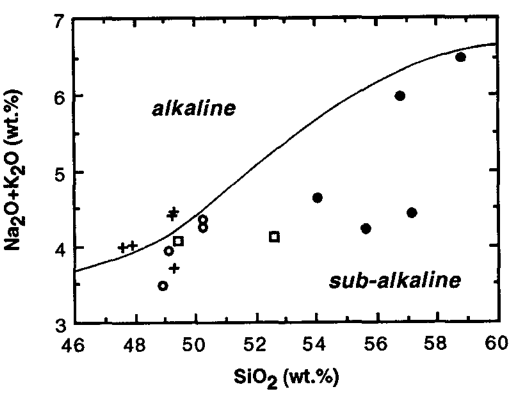

Fig. 4. Total alkali contents vs. SiO_2 variation diagram. The boundary between alkaline and subalkaline rocks is from Irivine and Baragar (1971). Symbols are the same as Fig. 2.

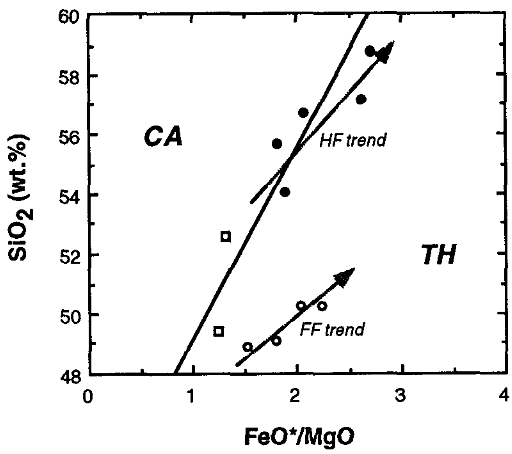

Fig. 5. FeO*/MgO vs. SiO_2 variation diagram. Miyashiro (1974) clarified that the calc-alkaline series (CA) has a steeper slope than tholeiite one (TH). Symbols are the same as Fig. 2.

ence of Nb contents between PF and the other rocks implies that the source materials and tectonic environment may be different.

DISCUSSION

The species and distribution of volcanic rock series in island-arcs and active continental margins are important because the chemical composition and volume of a certain magma series are directly related to arc maturity (Miyashiro, 1974). Immature island-arcs are dominanted by basalts and basaltic andesites of tholeiitic series, whereas mature island-arcs with a thick continental-type crust are andesites and dacites of tholeiitic and calc-alkaline series.

Total alkali versus SiO_2 diagram demonstrates that olivine basalts of PF fall in the field of alkaline series, while those of the other formations in sub-alkaline series (Fig. 4). The basalts of alkaline series generally have euhedral olivine phenocrysts having no reaction relation with pyroxene. The olivine basalts of PF also show this characteristics. Therefore, the geochemical features of PF well coincide with microscopic observation. In FeO*/MgO versus SiO_2 diagram (Fig. 5), basalts of FF show gentler slope than basaltic andesites and andesites of HF. Thus, it can be said that the rocks of FF have tholeiitic affinity, whereas those of HF have calc-alkaline one, though more felsic equivalents of each formation have not developed in the study area. Therefore, HF are produced in more mature island-arc environments than FF.

Tectonic discrimination diagram of primordial mantle-normalized pattern are widely used in order to interpret the volcanic rocks on terms of tectonic settings (Wood, 1979; McCulloch and Gamble, 1991). The discrimination diagrams of the studied igneous rocks are shown in Fig. 6. The KGI is early Tertiary magmatic island-arc where the Pacific plate (Aluk) subducted into the Antarctic peninsular (Smellie et al., 1984). Therefore, the average trace element abundances of island-arc calc-alkaline (IACA) and island-arc tholeiitic (IATH) basalts are plotted together for comparison. Trace element abundances in primordial mantle, IACA and IATH basalts are compiled in Table 3. Island-arc basalts are enriched in LILEs (large ionic lithophile elements) such as K, Rb, Ba and Sr, while depleted in HFSEs (high field strength elements) such as Ti, Nb, Zr and Y. HFSEs are derived from the mantle wedge without additional enrichment from the slab, because they are immobile during slab-fluxing processes (McCulloch and Gamble, 1991). On the other hand, the enrichment of LILEs is consistent with slab involvement, being due to the combination of their high rock-melt incompatibility and slab fluid mobility. The trace element patterns of the rocks in the study area have high LILEs/HFSEs ratios and negative anomalies of HFSEs (e.g., Ti,

Table 3. Trace element abundances of primordial mantle and representative basaltic rocks in various tectonic settings.

	primordial mantle*	island-arc tholeiitic**	island-arc calc-alkalic**	within plate tholeiitic**	within plate alkalic**	back-arc tholeiitic***
Ti	1177	3000	4650	13369	20000	8753
K	106	3240	8640	4151	9600	3569
Rb	0.1	4.6	14	7.5	22	6
Ba	1.2	110	300	100	380	77
Nb	0.31	0.7	1.4	13	53	8
La	0.31	1.3	10	35	7.83	
Ce	0.95	3.7	23	31.3	72	19.0
Sr	13.2	200	550	290	800	212
Zr	11.4	22	40	149	220	130
Nd	0.86	3.4	13	19	35	13.1
Sm	0.32	1.2	2.9	5.35	13	3.93
Y	4.1	12	15	26	30	30

*: Wood (1979)
**: Sun (1980)
***: Hawkesworth et al. (1977)

Nb and Zr), which are typical characteristics of basaltic rocks originated from island-arc environment. Birkenmajer et al. (1991) reported that the initial Sr isotope ratios of various kinds of rocks in KGI show relatively low values of about 0.7035. From the geochemical modelling based on Sr isotope ratios and incompatible element ratios, they suggested that the primary calc-alkaline magmas of KGI were all generated in an upper mantle modifid by addition of small amounts of pelagic sediments dragged by subduction processes.

Considering alkaline affinity of olivine basalts in PF compared with typical island-arc alkaline basalts, the incompatibility pattern of them has some exceptional features: that is, 1) their relative low abundances of total trace elements, and 2) their weak negative anomalies of HFSEs concentrations. In order to interpret these features, primordial mantle normalized patterns of typical within-plate tholeiite (WPTH), within-plate alkaline (WPAK) and back-arc tholeiite (BATH) basalts together with in Fig. 6 are shown in Fig. 7. Basalts of within-plate or back-arc generally show that the higher content and very weak negative anomaly of HFSEs. Thus, the chemical feature of trace elements in PF can be explained by consequence of mixing of island-arc type alkaline magma with within-plate (or back-arc) tholeiitic one. In summary, it is thought that the studied rocks were originated from the magmas generated by partial melting of upper mantle in island-arc environment, but the chemical compositions of each formation are variant with time and space.

Finally, we concentrate our discussion on the chemical variations of each formation, related to the arc evolution around KGI. In northeastern Japan arc, magma types of Quaternary basalts change across the island-arc from olivine tholeiite (OTB) through high-alumina basalt (HAB) to alkali olivine basalt (AOB) with increase in the depth of their origin (Kuno, 1966). Kuno's suggestion is supported by recent partial melting experiments under hydrous condition that the AOB, HAB and OTB magmas are segregated from the mantle wedge at about 1320°C and 23, 17 and 11 kbar, respectively (Tatsumi et al., 1983; Kushiro, 1990).

The chemical variation from tholeiitic affinity of FF to alkaline one of PF in KGI are similar to variation observed in NE Japan arc, although they are different in eruption time. Olivine basalts of PF are considered to have been formed during late Tertiary or Quaternary, while the others formed during early to middle Tertiary (Smellie et al., 1984). Pankhurst and Smellie (1983) have also shown that the magmatism became younger northeastward, along the length of the arc, a characteristic which was attributed to the shifting of subduction focus with time, probablly connected with a rotation of the

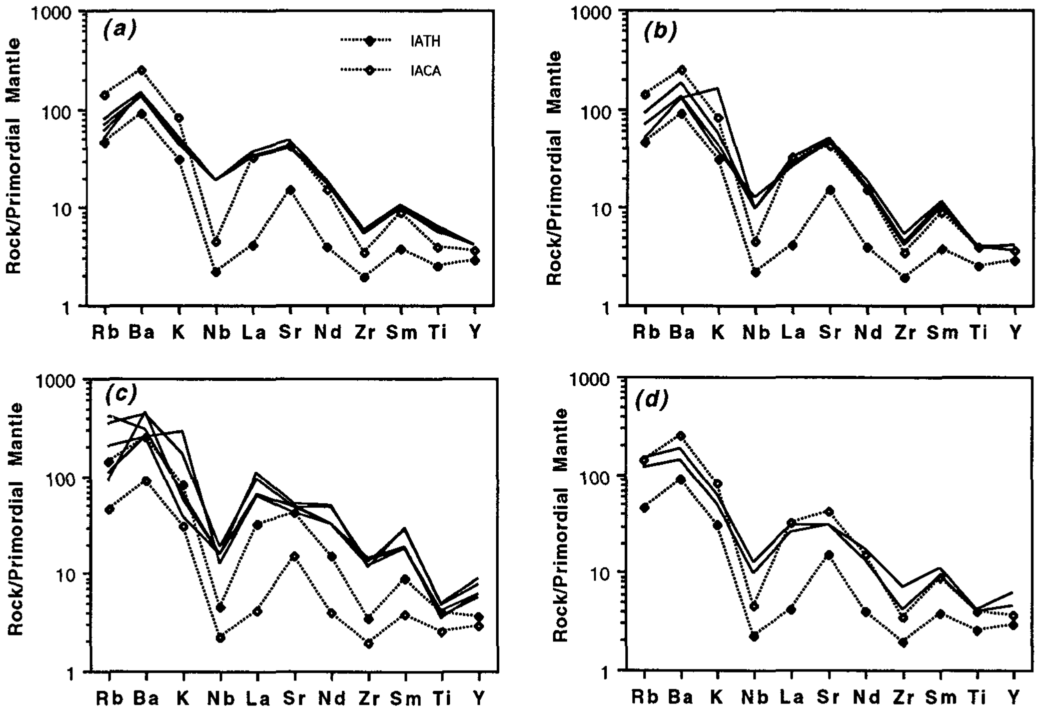

Fig. 6. Primordial mantle normalized trace elements patterns of each formation compared with island-arc calc-alkaline (IACA) and tholeiitic basalts (IATH). Normalized values are from Wood (1979). (a), Penguin Formation; (b), Fildes Formation; (c), Hennequin Formation; (d), Lions Rump Formation.

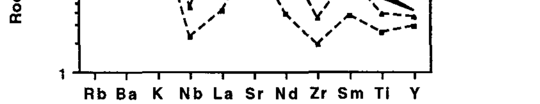

Fig. 7. Primordial mantle normalized trace elements patterns of Penguin Formation compared with the representative basaltic rocks in island-arc tholeiitic basalts (IATH), island-arc calc-alkaline basalts (IACA), within-plate tholeiitic basalts (WPTH), within-plate alkaline basalts (WPAK) and back-arc tholeiitic basalts (BATH).

Antarctic continental margin with recpect to the South Pacific plate. In this respect, the chemical variations of the volcanic rocks in KGI can be interpreted in terms of the change of subduction vector with time. The generation of PF magma having both island-arc type alkaline and within-plate (or back-arc) tholeiitic affinity might be related to the opening of Bransfield Strait during late Tertiary as well as the change of subduction mode around South Shetland Islands.

CONCLUSIONS

(1) The igneous rocks of study area are divided into four formations: 1) pyroxene basalt of Fildes Formation, 2) basaltic andesite, two-pyroxene andesite and augite andesite of Hennequin Formation, 3) pyroxene gabbro of Lions Rump Formation and 4) olivine basalt of Penguin Formation.

(2) The overall chemical features of each formation have their specific characteristics: that is, tholeiitic affinity of FF, calc-alkaline one of HF and alkaline one of PF.

(3) The trace elements abundance patterns illus-

trate that the volcanic rocks were originated largely from the magmas generated by partial melting of upper mantle in island-arc environments. However the trace elements in PF represents the mixing of island-arc type alkaline magma with within-plate (or back-arc) tholeiitic one.

(4) Transition from tholeiitic affinity of FF to alkaline one of PF in KGI resulted from the change of subduction mode with time. The generation of PF magma having alkaline affinity is considered to have been related to the opening of Bransfield Strait during late Tertiary as well as the change of subduction mode around SSI.

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