MAJOR ELEMENT CHEMISTRY OF METAMORPHIC ROCKS OF THE CAPE HINODE DISTRICT, EAST ANTARCTICA

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Abstract: Metamorphic rocks of the Cape Hinode district have the mineral assemblages of the amphibolite facies and have the chemical composition poor in K_2O even in SiO_2-rich rocks. They show lower K_2O/Na_2O and higher Fe_2O_3/FeO ratios than those of the Lützow-Holmbukta region. The fluorine content in metabasites of the Cape Hinode and Lützow-Holmbukta districts shows positive correlation with K_2O, and the F/K_2O ratio is slightly higher than that of the continental basalt series. The amount of fluorine decreases with increasing SiO_2 content in most of rock types.

1. Introduction

Geological and petrological investigations of the Cape Hinode district, 160 km northeast of Syowa Station in East Antarctica, have been carried out by YANAI and ISHIKAWA (1978). According to them, geology of the district is considerably different from that of the Lützow-Holmbukta region. The Cape Hinode district is characterized by the amphibolite facies metamorphic rocks, and is completely devoid of charnockite (pyroxene gneiss) whose presence is characteristic of the Lützow-Holmbukta region. Comparative study of metamorphic rocks between the Cape Hinode district and the Lützow-Holmbukta region seems to be important for clarifying the metamorphic characters of Antarctica.

In this study, major element chemistry and fluorine content of the metamorphic rocks of the Cape Hinode district will be described.

2. Brief Description of Analyzed Rocks

The samples analyzed here were collected by YANAI in December 1973 and January 1974 (JARE–15). According to YANAI and ISHIKAWA (1978), the Cape Hinode district is characterized by anorthositic gneiss and garnet-bearing anorthositic gneiss which is seen rarely in the Lützow-Holmbukta region. Subordinate rock types are garnet gneiss, hornblende gneiss, amphibolite, granites and metabasites. Pyroxene gneiss prominently found in the Lützow-Holmbukta region is completely absent in the Cape Hinode district.

Fourteen specimens of each rock type mentioned above were selected and analyzed chemically. Mineral assemblages of analyzed rocks are as follows:

1. Biotite amphibolite (Specimen No. 74010104)

This rock is found as a dyke in the anorthositic gneiss, at about 400 m south of Penguin Heights. It is composed of hornblende, biotite, quartz, plagioclase, apatite and ore.

2. Clinopyroxene bearing biotite amphibolite (No. 73123113)

This rock is distributed in the southern part of this district, and is concordant with the garnet bearing anorthositic gneiss and garnet gneiss. Constituent minerals are hornblende, biotite, plagioclase, quartz, clinopyroxene and ore.

3. Biotite-hornblende gneiss (No. 73123103)

4. Biotite-hornblende gneiss (No. 74010107)

5. Biotite-hornblende gneiss (No. 74010606)

6. Biotite-hornblende gneiss (No. 74010701)

7. Biotite-hornblende gneiss (No. 73123116)

These rocks are found within the anorthositic gneiss in the northwestern to the central parts of the district. They are composed of hornblende, biotite, quartz, plagioclase and ore.

8. Sillimanite-biotite-garnet gneiss (No. 74010304)

This rock occurs as a thin layer within amphibolite in the southwestern part of the district. Constituent minerals are garnet, sillimanite, biotite, quartz, plagioclase and ore.

9. Biotite gneiss (No. 73123106)

10. Biotite gneiss (No. 74010105)

11. Biotite gneiss (No. 74010115)

These are the most widespread rocks in the central and eastern parts of the district, and are called anorthositic gneiss by YANAI and ISHIKAWA (1978). Constituent minerals are biotite, quartz, plagioclase and ore. Potassium feldspar is rare.

12. Garnet-biotite gneiss (No. 74010113)

This rock is a member of the anorthositic gneiss and is found in the north of

Maigo Peak. The rock consists of biotite, garnet, quartz, plagioclase, potassium feldspar and ore.

13. Biotite granodiorite (No. 74010302)

Granitic rocks occur as discordant dykes and sheets in the amphibolite of the southern part of the district. This rock is composed of quartz, plagioclase and biotite with small amounts of potassium feldspar, ore and allanite.

14. Hedenbergite-garnet-plagioclase rock (No. 74010112)

This rock is found in the northwest of Maigo Peak as a small block included within hornblende gneiss. Constituent minerals are hedenbergite, garnet, plagioclase and ore.

The metamorphic rocks of the Cape Hinode district are completely devoid of charnockites and have the mineral assemblages of the amphibolite facies. Z-axial color of biotites is generally dark brown, and that of hornblendes is green to brownish green. In these features they are obviously different from biotites and hornblendes of the Lützow-Holmbukta region. It is characteristic that potassium feldspar is rate in the metamorphic and granitic rocks of the district. Garnet is not found in metabasites.

3. Results of Chemical Analyses

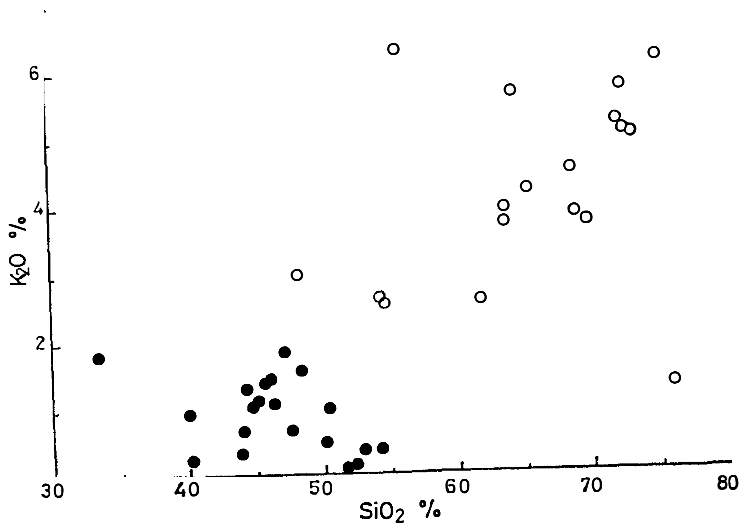
The analytical results are listed in Table 1, with CIPW norm. The SiO_2 content ranges from 38.78 to 75.90%, and other components show also wide variations except K_2O. Major element chemistry of rocks from the Lützow-Holmbukta region was summarized by YOSHIDA (1978). The chemical compositions of the two districts will be compared in some detail. The K_2O content of all rocks of the Cape Hinode district is nearly constant and does not exceed 2% even in the most acid facies. On the contrary, the K_2O content of rocks from the Lützow-Holmbukta region increases with increasing SiO_2 content (Fig. 1). Amphibolites of both districts are generally rich in Na_2O and have the ratio of $K_2O/Na_2O<1$, but most of charnockites and paragneisses around Lützow-Holmbukta are rich in K_2O and have the ratio of $K_2O/Na_2O>1$ (Fig. 2). Low K_2O is characteristic of the rocks from the Cape Hinode district, in comparison with those around Lützow-Holmbukta. Metabasites of the Lützow-Holmbukta region are generally rich in Na_2O+K_2O, hence they are plotted in the area of high-alumina basalt or alkali-olivine basalt on the alkali-silica diagram (YOSHIDA, 1978). Metabasites of the Cape Hinode district also show similar relations. However, the migration of major elements is not small (LAMBERT and HEIER, 1968), so that the estimation of rock series of original igneous rocks from major element chemistry must be made with some caution.

The rock No. 14 (Specimen No. 74010112) has anomalous chemical composition rich in Al_2O_3 and CaO and poor in SiO_2, MgO and alkalies. This may not be of a normal igneous and sedimentary origin, but might have been formed in an unusual

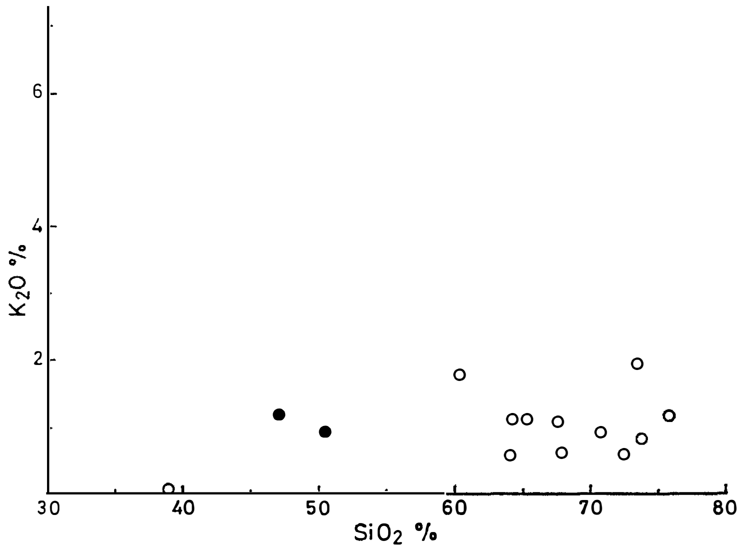
Table 1. Chemical analyses of rocks from Cape Hinode.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
SiO_2	47.02	50.56	64.17	64.30	65.43	67.72	68.01	60.54	70.80	72.60	73.89	75.90	73.79	38.78
TiO_2	2.44	1.81	0.41	0.52	0.45	0.32	0.33	1.40	0.21	0.04	0.12	0.27	0.35	0.26
Al_2O_3	14.76	12.93	19.34	16.73	18.42	18.14	17.77	17.55	16.88	17.36	15.88	13.44	14.14	24.44
Fe_2O_3	7.01	5.85	1.28	2.01	1.34	1.01	0.96	4.93	0.95	0.09	0.47	0.79	0.66	9.60
FeO	6.33	7.60	1.66	2.33	1.73	1.37	1.34	7.53	0.75	0.27	0.28	1.23	1.02	3.31
MnO	0.18	0.21	0.05	0.07	0.03	0.04	0.05	0.16	0.03	0.01	0.02	0.05	0.02	0.22
MgO	5.67	6.09	1.22	2.33	1.28	1.04	0.95	3.50	0.55	0.13	0.35	0.61	0.84	0.51
CaO	8.29	9.38	5.51	5.52	4.85	4.24	4.80	0.84	3.22	4.25	3.32	2.01	2.56	22.10
Na_2O	3.50	3.09	5.28	3.97	4.60	4.54	4.51	0.97	5.21	4.54	4.44	4.01	3.83	0.29
K_2O	1.20	0.95	0.60	1.13	1.14	1.09	0.65	1.81	0.95	0.62	0.83	1.17	1.98	0.06
H_2O+	1.61	1.40	0.38	0.66	0.38	0.39	0.53	0.70	0.48	0.21	0.36	0.30	0.58	0.55
H_2O-	0.39	0.16	0.23	0.27	0.14	0.17	0.14	0.27	0.30	0.12	0.15	0.13	0.21	0.24
P_2O_5	1.34	0.24	0.15	0.15	0.16	0.11	0.11	0.08	0.07	0.02	0.05	0.05	0.10	0.11
Total	99.74	100.27	100.28	99.99	99.95	100.18	100.15	100.28	100.40	100.26	100.16	99.96	100.08	100.47
Q	1.06	3.17	17.35	21.61	21.86	26.30	27.40	37.65	29.26	34.49	37.46	42.50	37.12	—
C	—	—	0.33	—	1.15	2.03	1.16	12.67	1.59	1.51	1.76	2.05	1.25	—
or (F)	7.12	5.62	3.56	6.67	6.73	6.45	3.84	10.73	5.62	3.67	4.89	6.89	11.73	0.33
ab (F)	29.61	26.10	44.64	33.54	38.88	38.36	38.09	8.17	44.02	38.36	37.52	33.90	32.38	0.08
an (F)	20.96	18.60	26.35	24.46	23.07	20.32	23.10	3.61	15.51	21.02	16.12	9.62	12.07	65.14
ne	—	—	—	—	—	—	—	—	—	—	—	—	—	1.29
wo (Di)	4.83	11.02	—	0.81	—	—	—	—	—	—	—	—	—	18.29
en (Di)	3.74	7.17	—	0.56	—	—	—	—	—	—	—	—	—	—
fs (Di)	0.55	3.08	—	0.18	—	—	—	—	—	—	—	—	—	—
en (Hy)	10.44	8.06	3.05	5.27	3.20	2.60	2.38	8.75	1.38	0.23	0.88	1.53	2.10	—
fs (Hy)	1.57	3.45	1.41	1.70	1.37	1.23	1.21	7.74	0.30	0.37	—	1.25	0.79	—
fo (Ol)	—	—	—	—	—	—	—	—	—	—	—	—	—	0.90
fa (Ol)	—	—	—	—	—	—	—	—	—	—	—	—	—	—
mt	10.16	8.49	1.86	2.92	1.95	1.46	1.39	7.15	1.37	0.14	0.63	1.14	0.95	10.63
il	4.64	3.44	0.78	0.99	0.85	0.61	0.62	2.66	0.40	0.08	0.23	0.52	0.67	0.50
hm	—	—	—	—	—	—	—	—	—	—	0.03	—	—	2.27
ap	3.16	0.57	0.37	0.37	0.37	0.27	0.27	0.20	0.17	0.03	0.13	0.13	0.24	0.27
mg	0.44	0.46	0.43	0.50	0.44	0.45	0.43	0.34	0.38	0.39	0.47	0.36	0.48	0.07
c	21.7	24.3	21.9	21.6	20.3	19.1	21.7	3.01	16.3	22.7	18.9	12.5	14.7	48.0
F ppm	985	680	242	366	411	264	203	670	152	<58	66	167	193	<51

Analyst: S. Kanisawa, F determination by K. Ishikawa.



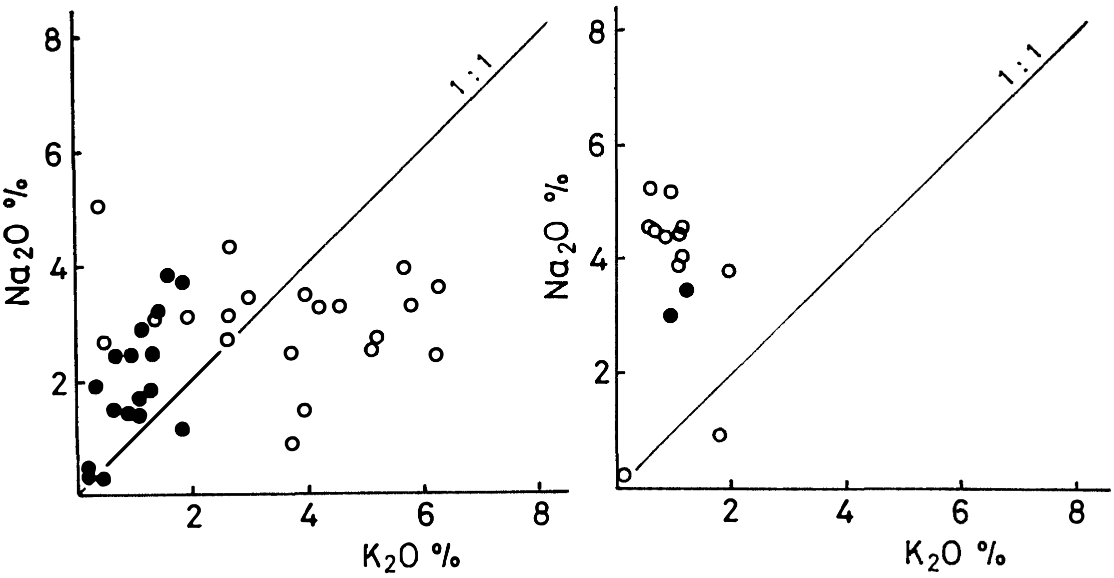
a. Rocks around Lützow-Holmbukta.



b. Rocks of the Cape Hinode district.

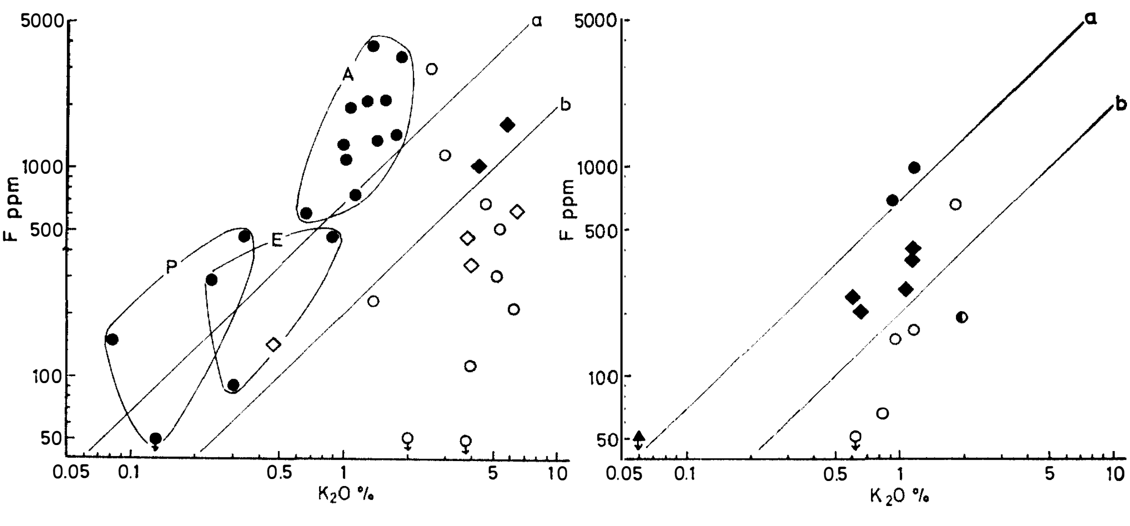
Fig. 1. SiO_2-K_2O diagram of rocks. Solid circles represent metabasites.

sedimentary environment or under metasomatism. Rocks of the Cape Hinode are rich in Fe_2O_3 and have higher Fe_2O_3/FeO ratio than those from Lützow-Holmbukta. The difference of the Fe_2O_3/FeO ratio in rocks between the Cape Hinode and Lützow-Holmbukta districts reflects the difference of metamorphic grade between the two districts. Decreasing Fe_2O_3/FeO ratio in metabasites with progressive metamorphism has been reported from various districts, for instance, the northwestern Adirondack Mountains (ENGEL and ENGEL, 1962). However, the difference of the



a. Rocks around Lützow-Holmbukta. *b. Rocks of the Cape Hinode district.*

Fig. 2. K_2O–Na_2O diagram of rocks. Solid circles represent metabasites.



a. Rocks around Lützow-Holmbukta. *b. Rocks of the Cape Hinode district.*

Fig. 3. K_2O–F diagram of rocks. Solid circle: Metabasite (A, amphibolite; E, eclogite; P, pyroxenite). Open diamond: Charnockite. Solid diamond: Hornblende gneiss. Open circle: Garnet-biotite gneiss and biotite gneiss. Solid triangle: Hedenbergite-garnet plagioclase rock. Half solid circle: Granodiorite. Lines a and b represent upper and lower limits of continental tholeiite–alkali basalt–peralkali basalt (ISHIKAWA et al., in preparation).

Table 2. Fluorine content of rocks around Lützow-Holmbukta.

Specimen No.	F ppm	Specimen No.	F ppm
Amphibolites		Charnockites	
68022405	1450	68032302	143
68091201-2	2110	68032402	345
68032703	1110	Y70020603	633
68040104	1370	Y69020309A	474
68051904	1960	Hornblende gneisses	
68032403	3470	68021508	1690
68012101	2180	68022607	1030
Y69020303	759	Biotite gneisses and a allied rocks	
Y70020518	3830	68090706	1190
Y69020307	608	68051908	3060
Y70020619	1330	68032313	685
Eclogites		68021514	114
68091201-1	292	68022002	237
68021509	465	Y69020618-C	<49
68032303	92	Y70020520	514
Pyroxenites		Y70020505	320
68032704	477	Y70020617	216
68032701	151	Y70020508	53
68032304	<50		
Anorthosite			
68032301	<54		

Analyst: K. ISHIKAWA.

K_2O/Na_2O ratio in hornblende gneisses and biotite gneisses may reflect that of lithology of the two districts.

Fluorine in bulk rocks from the Cape Hinode and the Lützow-Holmbukta districts was analyzed in the present study, with the results as listed in Table 2. The fluorine content is the largest in metabasites and decreases successively in hornblende gneisses and biotite gneisses (Fig. 3b); on the whole, it decreases with increasing SiO_2 content. Metabasites from the Lützow-Holmbukta region have a wide range of the F content from 3800 to <50 ppm, and the values are nearly correlative with the K_2O content (Fig. 3a). However, the F content in paragneisses does not show any correlation with K_2O and has also a wide range (3060 to <50 ppm). Positive correlation of K_2O and F in continental basalts (tholeiite-alkali basalt-basanite-nephelinite) and Japanese Quaternary basaltic rocks has been revealed by ISHIKAWA *et al.* (1979, in preparation). The F content of metabasites obtained here is somewhat higher in the F/K_2O ratio than that of continental basalts as shown in Figs. 3a and

3b. Migration of F, H_2O and K_2O during metamorphism is quite important and presents an interesting problem, but the data are still limited. The problem will be discussed in another paper with more detailed mineralogical data.

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