PETROLOGY OF THE LATE PLIOCENE BASALTS OF THE WESTERN PART OF HOKKAIDO

by

Yoshio ŌBA

(with 3 Text-figures and 4 Tables)

(Contribution from the Department of Geology and Mineralogy, Faculty of Science, Hokkaido University. No. 1220)

Abstract

In the western part of Hokkaido, many basaltic rocks were erupted in Neogene time. Petrological studies in the present paper are confine to basalts of late Pliocene age, because of their clear geologic relationship and freshness.

Generally, the basalts occur as lavas covering Pliocene formations, and as dikes intruding Miocene or Pliocene formations.

The late Pliocene basalts of this region are divided into two types; primitive alkali olivine basalt which were erupted in the eastern half of this region, and more differentiated olivine basalts, calc-alkaline basalts and basaltic andesites, in the wester half.

Lateral variation of petrography seems to reflect the geological conditions which influenced the fractionation trend of the magma.

It is concluded that late Pliocene basalts in this region were derived from a common parental alkali olivine basalt magma, but variation in compositions may be due to different conditions of fractional crystallization or due to magmatic assimilation of the basement rocks.

Introduction

The characteristic geology and petrology of Neogene Tertiary basalts of western Hokkaido has attracted the attention of many geologists. HUNAHASHI (1950, 1953) first pointed out that there are two contrasting types of basalt in this region. Later several geological quadrangle maps were published by the Geological Survey of Japan.* One of the authors of these maps, SATOH (1961) investigated the petrology of Etai-dake basalt complex.

The Takikawa-Fukagawa basin and the Kabato mountains are situated west of the Ishikari coal field and the Kamuikotan metamorphic zone. Geologically this region is peculiar and does not belong to the northern continuation of the

* Hamamasu, HATA et al (1957); Nishitoppu, HATA et al (1963); Kamietanbetsu, FUNAHASHI (1953); Utashinai, KAWANO et al (1956; Takikawa, KOBAYASHI et al (1956); Moseushi, KOBAYASHI et al (1969); Ofuyu, SATOH et al (1963); Kokuryo, SATOH et al (1964); Fukagawa, Suzuki (1953).

Green-tuff region of Southwest Hokkaido. Volcanism for example, is differs from that in other parts of Hokkaido; in that andesitic volcanism was prominent during Miocene to Pliocene time in its western part, ans basaltic volcanism occurred later throughout this entire region.

The Neogene basaltic rocks of western Hokkaido can be divided into two groups:

1. Lava flows and cones of late Pliocene time. These include two types of basaltic rocks distinguished by their distribution and petrography.
2. Small dikes and lava cones of basalt and dolerite. These basaltic rocks cut the Miocene to Pliocene formations.

Generally they suffer a little chloritization and zeolitization. The present paper treats only the former group. The latter group will be described in detail at another time.

Hitherto, little was reported about the chemical composition of basaltic rocks in this district. The author has made an attempt to remedy this lack of information. He also discusses the petrogenesis of the late Pliocene basalts.

Acknowledgement

The author wishes to express his sincere thanks to Professor Toshio ISHIKAWA of Hokkaido University for his invaluable teaching. Thanks are also due to Dr. Yoshio KATSUI of the same university and to Dr. Hiroyuki SATOH of the Geological Survey of Japan for giving useful discussion and advice, and to Dr. J. G. SOUTHER for his kindness in correcting the manuscript.

Geologic setting

Geology and tectonics of the region surrounding Takikawa-Fukagawa basin and Kabato mountains in western Hokkaido, have been described by many authors. These descriptions are summarized here, and a generalized geological map and distribution of Neogene basalts is shown in Fig. 1. The geological sequence is shown in Table 1.

The western part of Hokkaido can be divided into two geological provinces; an eastern half, adjacent to Takikawa-Fukagawa basin, and a western half including Kabato mountains and their northern extension.

1. The Takikawa-Fukagawa basin and its adjacent areas (area 1, in Fig. 1).

The geology of this province is characterized by a thick pile of Miocene to Pliocene sedimentary rocks. Its central part is covered by thick alluvial deposits forming the flood plain of the river Ishikari.

Basalts of this area were erupted as small lava cones, and intruded as dikes

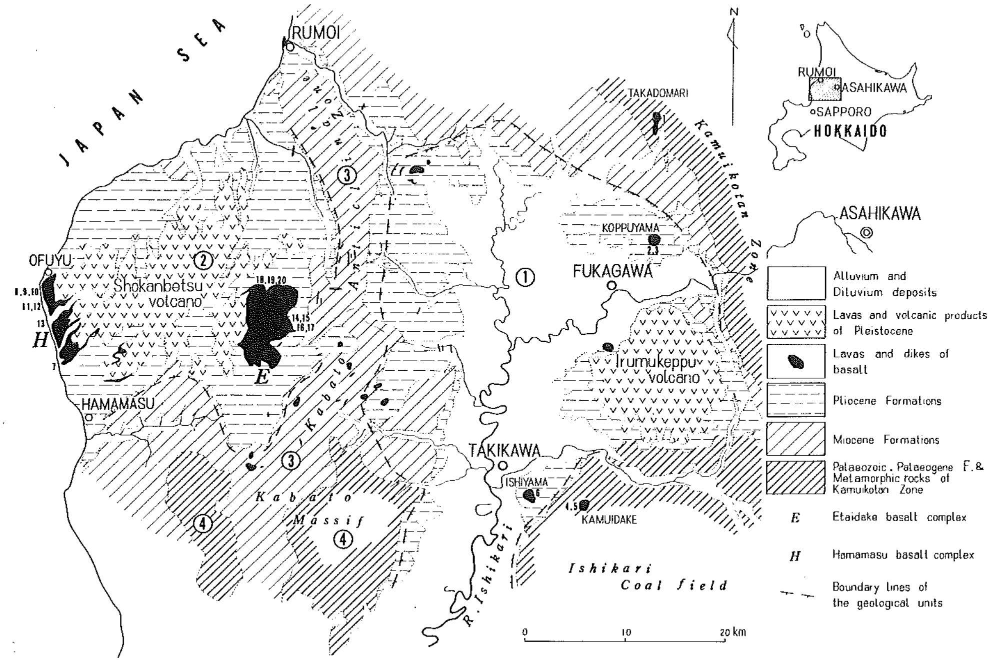

Figure 1. Generalized geological map of the western part of Hokkaido.
Geological units of this region:

1. Takikawa-Fukagawa basin and its adjacent area. In this area, the formations of Miocene and Pliocene time are thick, and relatively show gentle monoclinal structure.
2. The northern extending area of Kabato mountains. In this area, andesitic volcanics are predominant from Miocene to Quaternary time. Two large basalt complexes, the Hamamasu and Etai-dake basalts, are occurred.
3. Kabato anticlinal zone. In this area, formations of Miocene are moderately deformed by the N-S trend folding movement. Many small dikes and lava cones of basaltic (doleritic) rocks are occurred.
4. Kabato massif. It is the basement of Kabato mountains, and consists of Kumaneshiri formation (so-called Palaeozoic formation) and a little Paleogene formation.

This map is mainly compiled from the maps of Japan Geological Survey.

after the deposition of the Fukagawa groups.

2. The Kabato mountains (area 4, in Fig. 1) and their northern extension (area 3 in Fig. 1).

The basement in this province is composed of the pre-Tertiary Kumaneshiri formation. It is overlain by the Palaeogene Kabato formation, and both volcanic and sedimentary rocks of the Neogene Shintotsukawa and Nishitoppu group.

After middle Miocene time, andesitic volcanism became predominant in the western part of this area while in the eastern part, folding took place within the sedimentary rocks, producing the Kabato anticlinal zone.

Table 1. Geological sequence in the areas where the late Pliocene basalts are distributed.

age			area※	Utashinai-Fukagawa-Kamietanbetsu	Takikawa-Moseushi	Hamamasu-Ofuyu-Kokuryo
Quaternary				Alluvial and terrace deposits Volcanics of Irumukeppu	Alluvial and terrace deposits	Alluvial and terrace deposits Volcanics of Shokanbetsu volcano
				Basalt	Basalt	Basalt
Tertiary	Neogene	Pliocene	Fukagawa Stage	Takikawa Formation	Fukagawa Group	Horo and Iwao andesitic volcanics Moi and Rumoi Formation
Tertiary	Neogene	Miocene	Wakkanai S.		Shintotsukawa G.	Osatsunai and Mashike F.
Tertiary	Neogene	Miocene	Kawabata S.	Kawabata F.	Nishitoppu G.	Sakasagawa F. Hidarimata F.
Tertiary	Palaeogene			Poronai Group. Ishikari G	Kabato G.	
Pre-Tertiary				Kamuikotan metamorphic rocks	Kumaneshiri G.	

※The names of areas refer those on the geological maps.

All of these strata are covered by volcanic rocks of the Pleistocene volcano, Shokanbetsu.

Basaltic rocks of Miocene age, not treated in this paper, occurred as small dikes and lava cones, mostly in the Kabato anticlinal zone (area 3, in Fig. 1).

On the other hand, basaltic lavas of the late Pliocene Hamamasu and Etai-dake basalt complexes occur in the western part, on both sides of Shokanbetsu volcano. These two complexes are composed of thick piles of basaltic lavas and interbeded pyroclastics.

The former makes a large lava platform about 900 m above the sea level, whereas the latter is covered by younger volcanics and deeply dissected by river erosion and wave action of the Japan Sea.

Descriptions and petrochemistry of the basalts
Petrography

1. Basalts of the Takikawa-Fukagawa basin and its adjacent areas (the eastern basalts).

All basalts are dark grey to black in color, and compact. They contain phenocrysts of olivine and augite. The volume of olivine and augite vary inversely to one another, olivine forms 2.1-12.1% of the volume and augite 3.2-0%. It is notable that no phenocrysts of plagioclase and hypersthene are found. The groundmass consists of fine plagioclase laths, augite, olivine, alkali feldspar and iron ore. Sometimes biotite appears in the latest stage of crystallization. The texture is typical intergranular. No xenoliths, and no more highly differentiated basalt types are known to occur.

Chemically these basalts contain 46-48% SiO_2 (Table 2). All the basalts are

Table 2. Chemical analyses and norms of the late Pliocene basalts and associated andesites from the western part of Hokkaido.

	Basin type basalts						Hamamasu basalt complex		
	1	2	3	4	5	6	7	8	9
SiO_2	46.92	47.46	47.52	48.21	48.26	48.84	49.54	49.75	51.30
TiO_2	1.18	0.78	1.39	1.11	1.22	1.05	0.92	1.20	1.14
Al_2O_3	16.02	17.94	18.57	18.32	17.50	17.64	16.03	16.85	16.20
Fe_2O_3	3.60	5.20	4.58	2.69	2.96	3.54	3.17	5.53	4.48
FeO	6.56	4.66	5.15	5.39	6.09	5.34	5.98	5.31	5.03
MnO	0.10	0.15	n.d	0.18	0.17	0.14	0.18	0.19	0.23
MgO	10.37	6.73	7.27	8.33	8.26	7.74	8.20	6.21	6.71
CaO	10.29	11.11	10.82	10.70	10.24	11.06	9.73	10.01	9.56
Na_2O	2.61	3.13	3.03	3.15	2.52	3.15	2.64	3.36	3.15
K_2O	0.77	1.23	1.30	0.69	0.70	0.84	1.27	1.01	1.16
P_2O_5	0.09	0.40	n.d	0.31	0.25	0.22	0.62	0.37	0.34
H_2O^+	1.11	0.77	n.d	0.74	0.85	0.29	0.61	0.14	0.41
H_2O^-	0.89	0.46	0.59	0.44	0.74	0.33	0.65	0.59	0.35
Total	100.51	100.02	100.22	100.26	99.76	100.18	99.54	100.52	100.06
Q	–	–	–	–	–	–	–	–	1.17
Or	4.28	7.23	7.68	4.06	4.11	4.95	7.51	5.95	6.84
Ab	22.06	23.06	20.74	24.69	21.27	25.68	22.32	28.40	26.62
Ne	–	1.84	2.66	0.62	–	0.51	–	–	–
An	29.83	31.16	33.23	33.78	34.36	31.47	28.08	27.88	26.66
Di Wo	8.63	8.93	8.54	7.22	6.17	9.21	6.74	8.10	7.77
Di En	6.08	6.72	6.46	5.08	4.21	6.54	4.59	5.64	5.66
Di Fs	1.79	1.29	1.21	1.50	1.46	1.85	1.59	1.77	1.37
Hy En	–	–	–	–	9.30	–	11.10	6.21	11.11
Hy Fs	–	–	–	–	3.25	–	3.89	1.94	2.69
Ol Fo	12.94	7.06	8.16	11.02	5.00	8.96	3.37	2.57	–
Ol Fa	4.22	1.49	1.68	3.61	1.92	2.81	1.31	0.90	–
Mt	5.22	7.54	6.64	3.90	4.29	5.13	4.59	8.00	6.49
Il	2.08	1.49	2.64	2.11	2.13	1.92	1.75	2.28	2.17
Ap	0.20	0.94	–	0.74	0.60	0.50	1.47	0.87	0.47
Q	–	–	–	–	–	–	–	–	3.9
Di	48.0	62.0	56.4	47.5	37.8	58.9	39.6	57.2	59.7
Hy	2.1	–	–	–	40.1	–	46.0	30.0	46.4
Ol	49.9	31.3	34.3	50.4	22.1	39.4	14.4	12.8	–
Ne	–	6.7	9.3	2.1	–	1.7	–	–	–

Table 2 (continued)

Hamamasu basalt complex				Etai-dake basalt complex						
10	11	12	13	14	15	16	17	18	19	20
51.40	51.51	52.75	58.42	49.10	51.01	52.10	52.68	53.65	53.66	54.46
0.87	1.03	1.19	0.62	0.90	0.81	1.04	0.87	0.94	0.68	0.90
16.66	15.77	15.79	16.52	15.67	16.17	16.50	15.93	15.76	16.78	16.13
3.43	4.58	3.99	3.29	3.59	3.44	2.04	3.02	3.30	2.79	2.41
5.65	5.97	4.23	3.05	6.61	5.53	5.70	5.31	5.30	4.86	4.92
0.17	0.13	0.21	0.18	0.21	0.18	0.12	0.08	0.10	0.16	0.15
5.96	6.45	6.04	3.11	8.35	7.32	8.47	8.16	7.30	6.96	7.05
9.82	9.90	8.64	7.56	9.38	9.12	8.94	8.58	8.06	8.18	8.37
2.99	2.91	3.23	3.20	2.90	3.06	2.85	2.89	2.99	2.95	3.09
1.23	1.14	1.42	2.09	0.97	1.30	1.38	1.46	1.49	1.48	1.47
0.57	0.32	0.36	0.22	0.36	0.21	0.16	0.17	0.19	0.19	0.21
0.05	0.24	0.55	0.55	1.35	1.32	0.84	0.35	0.53	0.55	0.19
1.11	0.78	1.19	1.11	0.40	0.37	0.25	0.58	0.32	0.61	0.56
99.91	100.73	99.59	99.92	99.79	99.84	100.39	100.08	99.93	99.85	99.91
1.63	2.09	4.12	13.70	–	–	–	0.79	3.31	3.21	3.46
7.28	6.73	8.40	12.34	5.72	7.58	8.18	8.62	8.79	8.73	8.67
25.26	24.58	27.41	27.04	24.52	25.83	24.13	24.42	25.28	24.95	26.10
–	–	–	–	–	–	–	–	–	–	–
28.35	26.58	24.30	24.52	26.83	26.52	28.11	26.16	25.20	28.13	25.77
6.97	8.57	6.79	4.85	7.27	7.25	6.35	6.34	6.44	4.72	6.01
4.53	5.83	5.12	3.44	4.85	4.96	4.35	4.52	3.97	3.25	4.14
1.95	2.06	0.98	0.98	1.87	1.70	1.60	1.31	1.23	1.10	1.37
10.37	10.30	9.98	4.34	8.32	11.36	13.67	15.88	14.21	14.08	13.49
4.46	3.66	1.91	1.22	3.21	3.92	4.71	4.62	4.41	4.70	4.45
–	–	–	–	5.39	1.40	2.16	–	–	–	–
–	–	–	–	2.31	0.53	0.82	–	–	–	–
4.96	6.63	5.78	4.78	5.20	4.99	2.97	4.38	4.77	4.03	3.50
1.66	1.96	2.26	1.19	1.72	1.54	1.98	1.66	1.78	1.29	1.70
1.34	0.74	0.84	0.50	0.84	0.49	0.36	0.39	0.42	0.43	0.50
5.4	6.4	14.3	48.0	–	–	–	2.4	9.8	10.3	10.5
45.0	50.6	44.6	32.5	42.1	44.7	36.5	36.4	34.7	29.2	35.0
49.6	43.0	41.1	19.5	34.7	49.1	54:6	61.2	55.5	60.5	54.5
–	–	–	–	23.2	6.2	8.9	–	–	–	–
–	–	–	–	–	–	–	–	–	–	–

Analyst,
1. 2. 4. 6. 7. 8. 11. 14–20. Y. ŌBA } (in ŌBA et al, 1966 and ŌBA, 1968)
9. 10. 12. 13. S. TAGAMI }
3. Y. KATSUI (in SUZUKI, 1953)
5. K. MAEDA (in KAWANO et al, 1956)

1. Olivine basalt, containing 12.1% phenocrysts of olivine. Takadomari.
2. Olivine augite basalt, containing 2.7% phenocryst of augite and 2.1% phenocrysts of olivine. Koppuyama, north of Fukagawa City.
3. The same to 2.
4. Augite olivine basalt, containing 8.4% phenocrysts of olivine and 2.4% phenocrysts of augite, a few biotite is found in the crystalline groundmass. Kamui-dake, Utashinai City.
5. The same to 4.
6. Augite olivine basalt, containing 5.6% phenocrysts of olivine and 3.2% phenocrysts of augite. Ishi-yama, east of Takikawa City.
7. Augite olivine basalt, containing about 7% phenocrysts of olivine and a few dirty phenocrysts of plagioclase. Horo, north of Hamamasu.
8. Augite olivine basalt, upper most part of the Hamamasu basalt complex. Rich in olivine phenocrysts. Ofuyu, Mashike.
9. Augite olivine basalt, containing a few dirty phenocrysts of plagioclase. Ofuyu, Mashike.
10. Olivine bearing Augite basalt, Ofuyu, Mashike.
11. Olivine bearing augite basalt, contain resorbed phenocrysts of olivine and dirty phenocrysts of plagioclase. The groundmass has an andesitic, intersertal texture. Ofuyu, Mashike.
12. Olivine bearing augite basaltic andesite, containing a few relic phenocrysts of hornblende. Ofuyu, Mashike.
13. Hornblende bearing hypersthene augit andesite, a lava of the middle part of the Hamamasu basalt complex. Ofuyu, Mashike.
14. Augite olivine basalt, containing 13.3% phenocrysts of olivine and 1.6% phenocrysts of augite. A few dirty phenocrysts of plagioclase are found. Uryu-numa.
15. Augite olivine basalt, containing 4.5% phenocrysts of olivine and 3.3% phenocrysts of augite. The uppermost reaches of the river Penke-petan.
16. Olivine augite basalt, containing 10.7% phenocrysts of augite, 5.3% of phenocrysts of olivine and 9.7% phenocrysts of dirty plagioclase. The same locality as 15.
17. Olivine augite basalt, containing several % phenocrysts of olivine, augite and plagioclase. Rarely phenocrysts of hypersthene mantled by augite are found. The uppermost reaches of the river Penke-petan.
18. Augite olivine basaltic andesite, containing about 5% phenocrysts of olivine and plagioclase. Tomino-sawa, northern part of Uryu-numa.
19. Augite olivine basaltic andesite, containing several % phenocrysts of olivine and plagioclase. The same locality as that of 18.
20. Olivine augite basaltic andesite, containing 13.4% phenocrysts of plagioclase and several % phenocrysts of olivine and augite. 1.4% phenocrysts of hypersthene, mantled by augite are also found. Tomino-sawa.

high in Al_2O_3 and alkalies, and rich in normative olivine. Even the basalt lowest in silica typically contains about 0.8% of K_2O. The basalts are chemically silica-undersaturated alkali olivine basalt, although unusually rich in Al_2O_3. Rock types, according to the classification on mineral assemblage by KUNO (1950), are IIIb and IVb basalts.

The author (1968) had proposed the name of this type of basalt as "Basin type basalt", because it appears to be the characteristic basalt type in this region.

Basalts of similar petrochemistry also can be found in several other localities. To compare the petrochemical similarity of basalts, an index number was calculated, as follow by Regland (1968), between the average basin type basalt (standard) and each of several basalt types from Japan and the world. As shown in Table 3, the quantity of any main oxide in a certain basalt type is calculated from $\frac{|\% X - \% \text{standard}|}{\% \text{standard}}$, in the comparison with the standard.

Thus the sum of the quantities for the main oxides (sum of deviation) is obtained as an index number. The index number of the basin type basalt is of course zero, and consequently a basalt type with the lower index number is closer to the basin type basalt petrochemically.

From Table 3 it is clear that the basin type basalt is most similar to the average primitive basalts from the Japan Sea side of north-east Japan; the Ogi basalt, Sado island (YAMAKAWA and CHIHARA, 1968), and the Atsumi dolerite, Yamagata Prefecture (KUSHIRO, 1964).

It can be certainly be said that the basin type basalt ranks among many primitive basalts of the world. In view of the index number and alkalinity of these basalts, they lie between the Japanese alkali olivine basalts (KUNO, 1960, pp. 141, Table 6) and high-alumina basalt of Oregon Plateau (WATERS, 1962, pp. 165, Table 5).

2. Basalts of the Hamamasu and Etai-dake basalt complex (the western basalts).

These complexes consist mostly of lavas and pyroclastics of olivine bearing augite basalt and basaltic andesite. They contain abundant partly resorbed phenocrysts of olivine, though not more than those of the basin type basalt. The more basic types are compact and grey in color wereas more salic types are porphyritic and pale in color. Augite and plagioclase are the main constituent phenocrysts, and sometimes hypersthene rimmed by augite, is present.

It is worthy of note that the phenocrysts of plagioclase are partly resorbed and riddled with pyroxene and ore mineral grains. Xenoliths of crystalline or sedimentary rock are rarely found. The main rock types, occurring in this area are as follow;

Basalt IIIb, IIIb → c, IVb, IVb → c, IVc, (Xc), IIIa → d.

Basaltic andesite IIId, IVa → d, IVd.

The type in brackets is rarely found.

Chemically these basaltic rocks contain SiO_2 49-54%, and are relatively rich in alkalis, but they are slightly lower in Al_2O_3 than the basin type basalt (Table 2). The rocks are rich in normative hypersthene and sometimes normative quartz appears.

The comparative petrochemistry and genesis of these basalts is discussed in the following chapter.

Discussion

Petrographic and chemical studies on the basalts of western Hokkaido,

Table 3. Average chemical compositions of the basin type basalts and comparable primitive basalts of other provinces. (all values are recalculated water free)

	1	2	3	4	5	6	7
SiO_2	50.2	50.9	49.4	49.0	50.39	48.2	48.1
TiO_2	0.8	1.2	1.5	1.1	1.06	1.1	1.7
Al_2O_3	17.6	16.3	17.9	16.9	18.09	17.8	15.6
ΣFeO	10.3	11.2	10.3	9.0	8.13	9.6	10.3
MgO	7.4	7.4	7.0	8.1	9.00	8.2	9.3
CaO	10.5	8.9	10.0	11.9	9.00	10.9	10.4
Na_2O	2.8	3.0	2.9	3.1	3.17	3.0	2.9
K_2O	0.4	0.6	0.7	0.8	0.95	1.0	1.1
S.I.	35.7	32.9	33.7	38.9	38.7	38.0	39.7
N	11	19	21	10	2	5	7
Sum of deviation	1.20	1.08	1.02	0.46	0.56	0	1.07

$\Sigma FeO = FeO + 0.9 \times Fe_2O_3$

1. Japanese high-alumina basalt (KUNO, 1960).
2. Olivine tholeiite of northern Riogrande depression (LIPMAN, 1969).
3. High-alumina basalt magma of Oregon Plateau, U.S.A. (WATERS, 1962).
4. Original magma of Ogi basalt, lower Siraki zone (YAMAKAWA and CHIHARA, 1968).
5. Original magma of the Atsumi dolerite, lower Kayaoka sheet (KUSHIRO, 1964).
6. Basin type basalt (this paper).
7. Japanese alkali olivine basalt (KUNO, 1960).

$$\text{S.I.: Solidification index,} = \frac{100 \times MgO}{MgO + FeO + Fe_2O_3 + Na_2O + K_2O}$$

(KUNO, 1957, pp. 564)

N: Number of analyses involved in calculating the average.
Sum of deviation: The sum, for all oxided in Table, of the quantity;

$$\frac{|\%\,X - \%\,\text{standard}|}{\%\,\text{standard}}$$

Where X is the oxide abundance in the comparison basalt, and standard is the same oxide abundance in the basin type basalt.

suggest that there are two different types of late Pliocene basalts.

The basin type basalts in the eastern half of this region are uniform in their mineralogy and chemistry, and seem to represent a primitive alkali olivine basalt; while the Hamamasu and Etai-dake basalt complex in the western half, consists of more highly differentiated olivine basalts and calc-alkaline basaltic andesites. The former were erupted through relatively monotonous thick sedimentary rocks of the sinking basin, whereas the latter were emplaced under much more complicated geotectonic condition, cutting through sedimentary rocks with abundant volcanic products.

Petrochemical characteristics of the basalts of this region are expressed most clearly in the silica-alkali and normative Q-Di-Hy-Ol-Ne diagrams (Figs. 2 and 3).

In fig. 2, all these basalts are seen to fall on a curve intersecting the boundary between the alkali basalt field and tholeiite field of Hawaiian lavas (MACDONALD, 1968), or that of the alkali rock series and the high-alumina basalt series of Japanese volcanic rocks (KUNO, 1965).

According to the classification of basalts proposed by YODER and TILLEY (1962), the basalts of this region are separated into two groups on the normative Q-Di-Hy-Ol-Ne diagram; the basin type basalts are typical undersaturated olivine basalt, whereas the Hamamasu and Etai-dake basalts range from olivine tholeiite to quartz tholeiite field (Fig. 3).

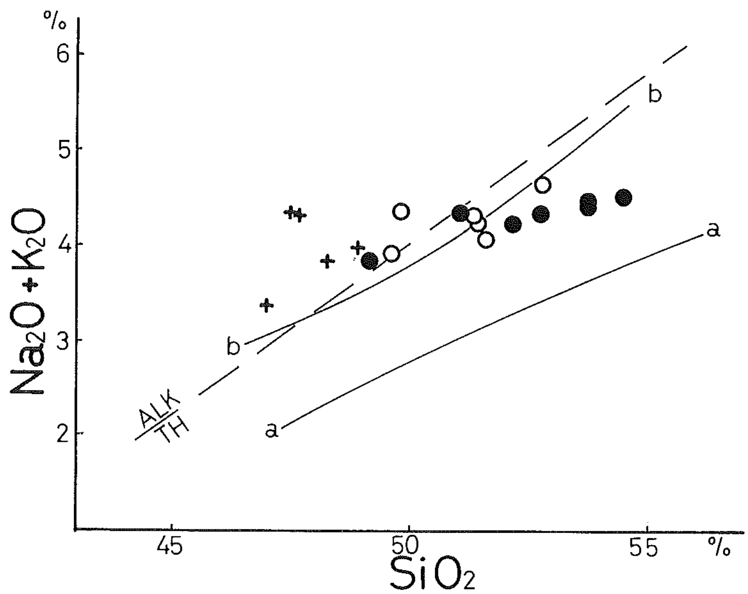

Figure 2. The Silica-Alkali diagram.

+ Basalts of the Takikawa-Fukagawa basin and its adjacent areas: So called "Basin type basalt".

● and ○ : Basalts of the Etai-Dake (full circle) and Hamamasu (open circle) basalt complex.

ALK/TH : The boundary line between the tholeiite and alkali rock series of Hawaii lavas. (MACDONALD,1908)

a—a : The boundary line between tholeiite and high-alumina basalt. (KUNO, 1965)

b—b : The boundary line between high-alumina basalt and alkali basalt. (KUNO, 1965)

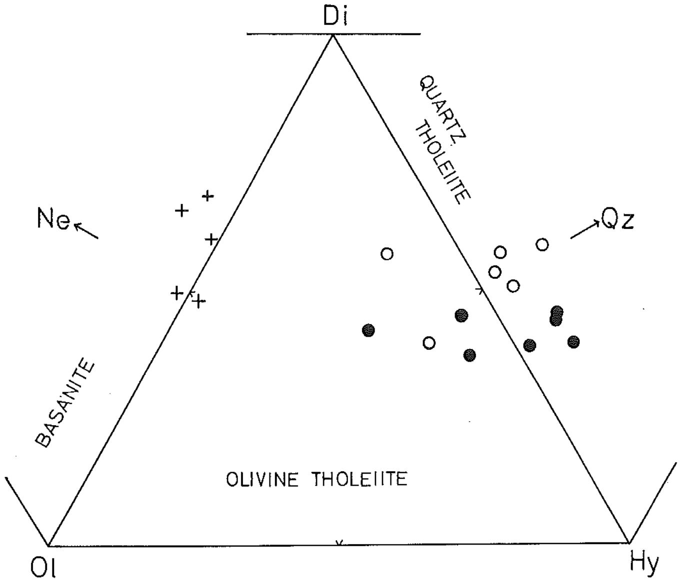

Figure 3. The normative Q-Di-Hy-Ol-Ne diagram. Symbols are the same as in Figure 2.

Chemical composition of the basin type basalt is uniform and seems to be little different from those of the parental magma as a result of their slight-fractional crystallization. On the other hand, basalts of the two basalt complexes in the western half of this region are considered to be derived from the same parental magma of basin type basalt, by complicated process of crystallization.

From another point of view, the author has attempt to make a simple model of the fractional crystallization of a magma, to explain the variation in composition of basalt in this region. Assuming that the average composition of the basin type basalt is a parental magma (Table 4-1), and only simple crystal fractionation controls the differenciation trend, there exist the following possibilities, for example, in the case of the Etai-dake basalts:

(1). The most mafic basalt (Table 4-2) would be derived from the parental magma by removal of plagioclase crystals which may precipitating most markedly in this stage.

(2). The most salic basaltic andesite (Table 4-3) would be derived from the liquid chemically corresponding to the basalt of Table 4-2, by removal of olivine and pyrozene crystals.

The reason why the trend of fractional crystallization changed after the formatiom of the most mafic magma of Etai-dake basalts (Table 4-2) is not clear, but the change of the physical conditions during crystallization or assimilation of basement rocks by magma, as mentioned by SATOH (1961), are

Table 4. Compositional addition and subtraction of main oxides among the representative rocks.

	1		2			3	
SiO_2	48.2	⇨	+1.9	50.1	⇨	+4.8	54.9
Al_2O_3	17.8		−1.8	16.0		+0.3	16.3
ΣFeO	9.6		+0.4	10.0		−2.7	7.3
MgO	8.2		+0.3	8.5		−1.4	7.1
CaO	10.9		−1.3	9.6		−1.2	8.4
Na_2O	3.0		−0.1	2.9		+0.2	3.1
K_2O	1.0		0.0	1.0		+0.5	1.5

1: Average composition of the basin type basalt.
2: Most mafic basalt of the Etai-dake basalts.
3: Most salic basaltic andesite of the Etai-dake basalts.
(All values are recalculated water free)

possible. The presence of dirty phenocrysts of plagioclase in the Etai-dake basalts cannot be overlooked in this respect.

Chemical composition of the basin type basalt is uniform, as mentioned previously, and seems to be close to the primitive basalt magma. The cause for absence of phenocrystic plagioclase is not certain, but it may be attributed to the crystallizing condition, in which the solidus temperature is abnormally lowered; i.e. crystallization of plagioclase in intratelluric stage is prevented at moderate depth (15 – 35 km), following the theory proposed by GREEN and RINGWOOD (1967).

As shown in Fig. 2, basalts of this region extend across the alkali basalt field into the tholeiitic* rock field; this feature appears with the petrography of the basalts. Such associations of alkali olivine basalts and calc- alkali basalts or andesites, derived from the same common magma, are also known in Southwest Japan (AOKI and OJI, 1966).

These results corroborate the conclusion that the parental magma of the late Pliocene basalts of this region is alkali olivine basaltic, and the variation of the basalts is attributed to differences of geological circumstance.

Concluding remarks

The late Pliocene basalts of western Hokkaido, can be divided into two distinct types.

Primitive alkali olivine basalts.

1. Uniform in their chemical and mineralogical compsotions.
2. A little rich in alumina but free from phenocrysts of plagioclase.
3. Erupted in the Takikawa-Fukagawa basin and its adjacent areas where

* The term "tholeiite" is not a suitable name for all basalts, which plot in the tholeiite field or high-alumina basalt field of Fig. 2. Basalts of the Hamamasu and Etai-dake complexes belong to the calc-alkali rock series, defined by KUNO (1965).

thick, normal sedimentary rocks are predominant.

More differentiated basalts and basaltic andesites.

1. Various kinds of rocks are found; from olivine basalt to calc-alkali basaltic andesite.
2. Dirty phenocrysts of plagioclase are found. Sometimes, relic phenocrysts of hornblende and xenoliths are detectable.
3. Erupted in the areas where more complicated geotectonic movement and volcanism had occurred during Miocene and Pliocene age.

Although the results are not yet conclusive, the author considers that the two types of basalts could be derived from a common parental magma. It appears also, that the occurrence of two chemically distinct basalt provinces in this region is related to differences in the process of fractional crystallization.

References

AOKI, K., and OJI, Y. (1966): Calc-alkaline volcanic rock series derived from alkali-olivine basalt magma. Jour. Geoph. Res., **71**, 6127 – 6135.

GREEN, T.H. and RINGWOOD, A.E. (1967): Genesis of basaltic magmas. Cont. Mineral. Petrol., **15**, 103 – 190.

HATA, M., and YAMAGUCHI, S. (1957): Explanatory text of the geological map of Japan. 1:50,000 Hamamasu. Geol. Surv. Japan. (in Japanese).

HATA, M., SATO, H., KAKIMI, T., YAMAGUCHI, S., and KOBAYASHI, I. (1963): Explanatory text of the geological map of Japan. 1:50,000 Nishitoppu. Geol. Surv. Japan. (in Japanese)

HUNAHASHI, M. (1950): Basalts of the Uryu-Sorachi district. The Cenozoic Research (Shinseidai no Kenkyu), **5**, 1 – 6. (in Japanese).

——————— (1953):Some problems basalt. Earth Science (Chikyu Kagaku), **10**, 1 – 14. (in Japanese)

——————— (1953):Explanatory text of the geological map of Japan.) 1:50,000 Kamietanbetsu. Geol. Surv. Japan. (in Japanese)

KAWANO, Y., MATSUI, K., and SHIMIZU, I. (1956): Explanatory text of the geological map of Japan. 1:50,000 Utashinai. Geol. Surv. Japan, (in Japanese)

KOBAYASHI, I., KAKIMI, T., UEMURA, T., and HATA, M. (1956): Explanatory text of the geological map of Japan. 1:50,000. Takikawa. Geol. Surv. Japan. (in Japanese)

KOBAYASHI, I., HATA, M., YAMAGUCHI, S., and KAKIMI, T. (1969): Explanatory text of the geological map of Japan. 1:50,000. Moseushi. Geol. Surv. Japan. (in Japanese)

KUNO, H. (1950): Petrology of Hakone volcano and the adjacent areas, Japan. Bull. Geol. Soc. America, **61**, 957 – 1020.

KUNO, H. (1953): Volcanoes and volcanic rocks. Iwanami Book Co., Ltd. (in

Japanese)

KUNO, H., YAMASAKI, K., IIDA, C. and NAGASHIMA, K. (1957): Differentiation of Hawaiian magmas. Japanese Jour. Geol. Geograph., **28**, 179 – 218.

KUNO, H. (1960): High-alumina basalt. Jour. Petrology, **1**, 121 – 145.

KUNO, H. (1965a): Some problems on calc-alkali rock series. Jour. Japan Assoc. Min. Petr. Econ. Geol., **53**, 131 – 142. (in Japanese)

KUNO, H. (1956b): Fractionation trends of basalt magmas in lava flows. Jour. Petrology, **6**, 302 – 321.

KUSHIRO, I. (1964): Petrology of the Atsumi dolerite, Japan. Jour. Fac. Sci. Tokyo Univ., Sec. II, **15**, 135 – 202.

LIPMAN, P.W. (1969): Alkalic and tholeiitic basaltic volcanism related to the Rio-Grande depression, southern Colorado and northern New Mexico. Geol. Soc. America, **80**, 1343 – 1354.

MACDONALD, G. (1968): Composition and origin of Hawaiian lava flows. Studies of volcanology, Geol. Soc. America, Memor 116, Howell Williams Volume, 447 – 522.

ŌBA, Y., and TAGAMI, S. (1966): Petrology of the Tertiary basalts of Hamamasu, Hokkaido, Japan. Jour. Japan Assoc. Min. Petr. Econ. Geol., **56**, 235 – 245. (in Japanese)

ŌBA, Y. (1968): Petrological study of the Neogene basalts from the western part of Hokkaido. 1. The basic type basalts of Takikawa-Fukagawa district. Jour. Japan Assoc. Min. Petr. Econ. Geol., **60**, 222 – 227. (in Japanese)

RAGLAND, P.C., ROGERS, J.J.W. and JUSTUS, P.S. (1968): Origin and differentiation of Triassic dolerite magmas, North Carolina, U.S.A. Contr. Miner. Petr. **25**, 1 – 24.

SATOH, H. (1961): The Etai-dake basalt complex. Jour. Geol. Soc. Japan., **67**, 313 – 322. (in Japanese)

SATOH, H., SAWAMURA, K. and YAMAGUCHI, S. (1963): Explanatory text of the geological map of Japan. 1:50,000. Ofuyu. Geol. Surv. Japan. (in Japanese)

SATOH, H., HATA, M., KOBAYASHI, I., YAMAGUCHI, S. and ISHIDA, M. (1964): Explanatory text of the geological map of Japan. 1:500,000 Kokuryo. Geol. Surv. Japan. (in Japanese)

SUZUKI, J. (1953): Explanatory text of the geological map of Japan. 1:50,000. Fukagawa. Geol. Surv. Japan. (in Japanese)

WATERS, A.C. (1962): Basalt magma types and their tectonic associations: Pacific northwest of the United States. American Geoph. Union, Geoph. Monograph, **6**, 158 – 170.

YAMAKAWA, M. and CHIHARA, K. (1968): Petrology of Ogi basalt: part 1. Petrochemistry. Sci. Rept. Niigata Univ. Ser. E. Geol. Miner, No. 2, 41 – 79. (in Japanese)

YODER, H.S. Jr., and TILLEY, C.E. (1962): Origin of basalt magma: An experimental study of natural and synthetic rock systems. Jour. Petro., **3**, 342 – 532.

(Manuscript received August 31, 1971)