PETRO-CHEMICAL STUDY ON THE LAVAS FROM VOLCANO RISHIRI, HOKKAIDO, JAPAN

By

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(With 5 Tables and 8 Figures)

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Introduction

Rishiri island is an extinct volcano situated in the north-eastern part of the Japan Sea, to the west of Wakkanai city in northern Hokkaido (Fig. 1). It forms a beautiful conical volcano (1718 meters above sea level)with many younger parasitic cones on its flanks.

Up to present, no geological investigation on this volcano has been made except by ABE[1] and a few others. ABE investigated the geology in detail and published a geological map and 3 chemical analyses of the lavas. Prior to his investigation, a few geological items on this volcano had been published: Volcano Rishiri had been said to be a ruined strato-cone built up chiefly of pyroxene-andesite ;[2][3] and the problem to what volcanic zone this volcano must be related had been discussed by several geologists.[2][4][5][6] It was advocated by KÔZU and WATANABE[5] from the petrographical point of view that this volcano belongs to the Nasu zone, and even now this view is accepted. We must, however, note the tectonic stand-point of AKAGI[6] that the northern part of the Nasu zone should be regarded as independent of its main part; that is, as the Rishiri zone.

The writer carried out field work on this volcano during several weeks of the last two summers followed by laboratory work, including chemical analysis of 7 lavas.

The lavas from this volcano vary from olivine-augite-basalt to hypersthene-andesite, ranging from 49.26% to 66.41% in silica contents, and are characterized by a paucity of hornblende and quartz. A general characteristic of their chemical compositions is their comparative richness in alkalies, especially in soda, and also lowness in *al-alk* of NIGGLI's value, contrary to the general characteristic of the Nasu zone which was recently noticed by ISHIKAWA.[7]

In this paper, the writer describes the geology of this volcano briefly, and then the chemical compositions of the lavas, considering their chemical compositions in reference to the general characteristic of the Nasu zone and to that of Oshima-ôshima which belongs to the Chôkai (or Kanpû) volcanic zone along the inner arc of Japanese islands.

In publishing this paper, the writer wishes to express his cordinal thanks to Prof. T. ISHIKAWA for valuable instructions received throughout this study, and to the menbers of the Department of Geology and Mineralogy, Hokkaido University, for many advices during the work. The writer is also indebted to Mr. A. ABE for the geological map and its explanations in this paper. Thanks are likewise due for a grant from the Scientific Research Fund of the Department of Education which was used for this study.

Geological Summary of Volcano Rishiri

The general geological map of Volcano Rishiri shown in Figure 1 was prepared by ABE, slightly modified by the writer. The geological history of this volcano can be induced from this map and its explanations (Table I).

Volcano Rishiri is a strato-cone formed by a central eruption on the base of a low hill composed of Pliocene sediments and igneous rocks, with many parasitic cones on its flanks. The summit of the main body has suffered from intense erosion, while the skirts are covered by volcanic detritus and fan deposits. No indication of volcanic activity is shown in this volcano at present.

The crater of the main body has vanished from sight by erosion, but it can be estimated that the crater was situated on the south of the present summit, judging from the dips and courses of lava flows and from the orientations of radial dykes. Most of the parasitic cones show their original form with more or less complete craters, in contrast

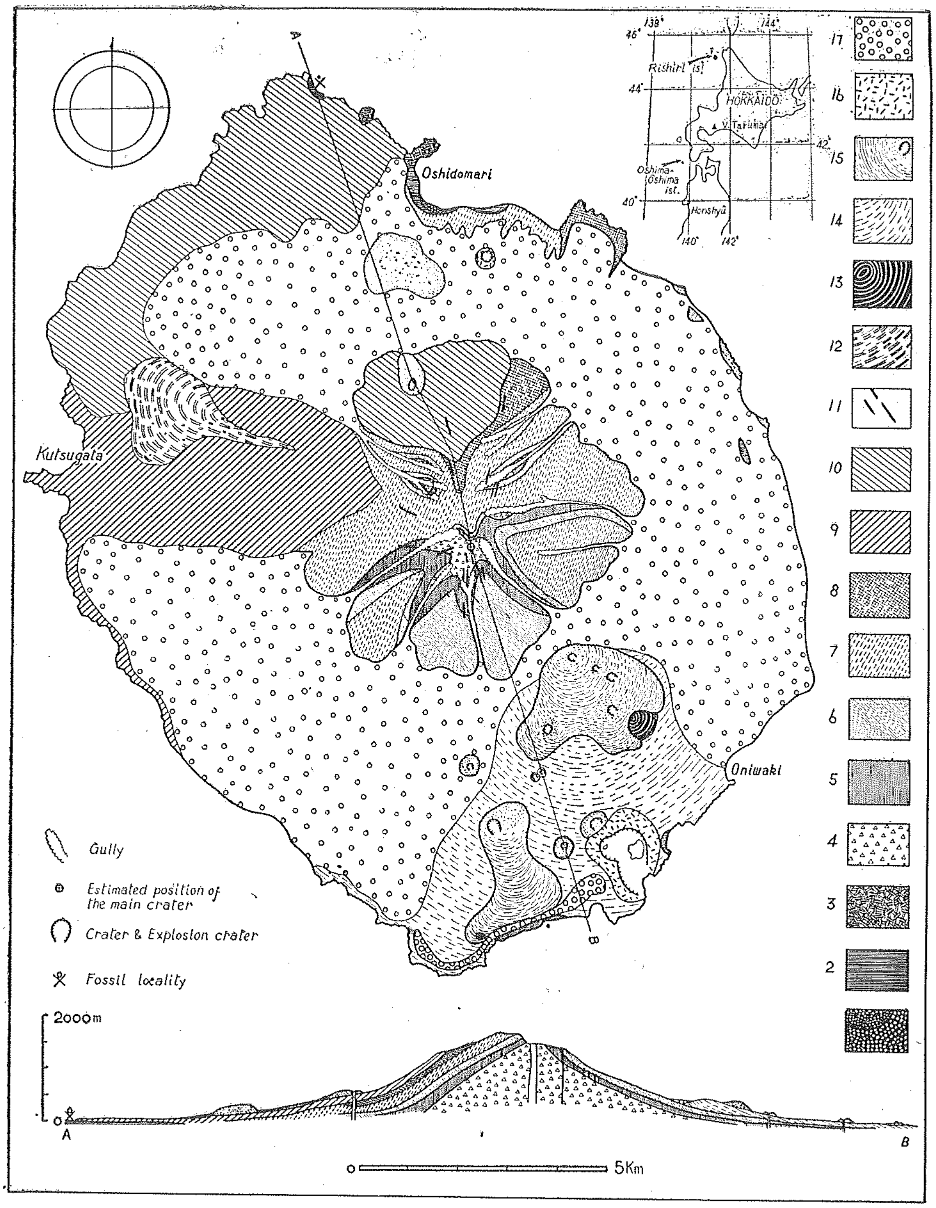


Figure 1. Geological map of Volcano Rishiri by A. ABE, 1934. (Slightly modified by the writer. Numbers of the legend refer to Table I.)

TABLE I. Explanation of the Geological Map.

Erosion products	17.	Volcanic detritus and fan deposit.
Products from the parasitic craters of Volcano Rishiri (Holocene)	16.	Explosion products.
	15.	Cinders and lava flows (olivine-augite-basalt).
	14.	Oniwaki lava flow (olivine-augite-basalt)[*1].
	13.	Ishiyama dome lava (hypersthene-andesite)[*9].
	12.	Tanetonnai lava flow (augite-hypersthene-andesite).
Products from the main crater of Volcano Rishiri (Pleistocene ? to Holocene)	11.	Radial dykes (olivine-augite-basalt[*2], augite-hypersthene-andesite, etc).
	10.	Motodomari lava flow (olivine-augite-basalt)[*5].
	9.	Kutsugata lava flow (olivine-augite-basalt)[*6].
	8.	Notsuka lava flow (olivine-augite-basalt)[*3].
	7.	3rd ejecta, lava flows and agglomerates (augite-hypersthene-andesite)[*7].
	6.	2nd ejecta, lava flows and agglomerates (olivine-augite-basalt)[*4].
	5.	1st ejecta, lava flows and agglomerates (augite-hypersthene-andesite)[*8].
	4.	Early ejecta, agglomerates (augite-hypersthene-andesite).
Basement rocks (Pliocene)	3.	Dykes (hornblende-augite-hypersthene-andesite)
	2.	Tuffaceous mudstone in which *Mactra* sp., *Tellina* sp., *Gastropoda*, *Teleostei* and *Diatom* occur.
	1.	Lava flow and agglomerate (augite-hypersthene-andesite).

Numbers from 1 to 17 show the geological succession in Rishiri island older to younger, except numbers 11 and 12 : 11 stands for the radial dykes which intruded during and following the eruption of the main volcano; and the date of the extrusion of Tanetonnai lava flow (12) may be contemporaneous to that of Ishiyama dome lava.
The stars (*) indicate the numbers of chemiacl analysis with reference to Table II.

to that of the main volcano. It is very interesting that the parasitic cones arrange on the north and south flanks of the main volcano, while there is none on the west and east. Added to this, the radial dykes are concentrated on the south and north sides of the summit.

It can be supposed that the tectonic line crosses through the main body from south to north.

Chemical Compositions of the Lavas from Volcano Rishiri

Among the products from Volcano Rishiri, the analysed lavas are 9 in sort as shown in Tables I and II. The lavas from this volcano are divisible petrographycally into 3 types: olivine-augite-basalt (SiO_2 $=49.26$–53.29%), augite-hypersthene-andesite ($SiO_2=58.44$–63.48%) and

TABLE II. Chemical compositions of the lavas from Volcano Rishiri.

wt %	1	2	3	4	5	6	7	8	9
SiO_2	49.26	49.58	49.60	50.69	50.78	53.29	58.44	63.48	66.41
TiO_2	1.25	1.41	1.40	1.28	1.09	—	—	.56	.55
Al_2O_3	17.71	16.88	16.06	16.59	15.55	18.14	17.12	16.89	16.20
Fe_2O_3	2.67	4.19	4.05	4.06	3.90	3.63	2.36	2.82	1.98
FeO	7.12	5.97	7.10	5.01	7.02	5.12	4.31	2.77	2.93
MnO	.05	.25	.21	.10	.12	—	—	.10	.09
MgO	7.91	5.29	6.12	7.34	7.06	5.02	2.70	2.54	1.55
CaO	10.01	10.75	10.86	10.00	9.82	9.83	7.24	6.21	3.46
Na_2O	3.08	3.85	2.76	3.49	3.75	3.48	3.62	4.04	5.14
K_2O	.56	.88	.86	1.03	.59	1.17	1.13	.97	1.74
P_2O_5	.19	.08	.17	.14	.07	—	—	.14	.17
$H_2O(+)$	.36	.61	.54	.43	.30	—	—	.20	.25
$H_2O(-)$	.17	.24	.12	.18	.20	—	—	.05	.05
Total	100.34	99.98	99.85	100.32	100.20	99.68	96.92	100.77	100.52

(1) Oniwaki lava (Olivine-augite-basalt), southern shore of Oniwaki.
(2) Dyke (Olivine-augite-basalt carrying a few biotites and muscovites), Rôsokuiwa near the top of Volcano Rishiri.
(3) Notsuka lava (Olivine-augite-basalt carrying a few biotites), Sainokawara, north of the summit of Volcano Rishiri.
(4) Lava of 2nd ejecta (Olivine-augite-basalt), eastern side of the top of Volcano Rishiri.
(5) Motodomari lava (Olivine-augite-basalt), northern coast of Rishiri island.
(6) Kutsugata lava (Olivine-augite-basalt), shore of Kutsugata.
(7) Lava of 3rd ejecta (Augite-hypersthene-andesite), summit of Volcano Rishiri.
(8) Lava of 1st ejecta (Augite-hypersthene-andesite), eastern ridge of Volcano Rishiri.
(9) Ishiyama dome lava (Hypersthene-andesite), Ishiyama, west of Oniwaki.
Nos. (6) and (7) analyzed by A. ABE,(1) and other 7 by the writer.

hypersthene-andesite (SiO_2=66.41%). These mineral assemblages are rather simple. Basalts usually show intersertal texture with or without a little brown glass, and consist mainly of plagioclase (An72–An40 in phenocryst, An70–An28 in groundmass), augite ($+2V=56°–44°$ in phenocryst, $+2V=50°–42°$ in groundmass) and olivine ($-2V=90°–82°$ in phenocryst, $-2V=90°–74°$ in groundmass), sometimes carrying slight amount of biotite and muscovite as interstitial minerals, but no silica mineral in any specimens. Augite-hypersthene-andesites are strongly porphyritic in texture usually with glass, and composed mainly of plagioclase (An60–An38 in phenocryst, An43–An33 in groundmass), hypersthene ($-2V=72°–69°$ in phenocryst, $-2V=70°$ in groundmass, both with week pleochroism) and augite ($+2V=51°–43°$ in phenocryst, lacking in groundmass), usually with cristobalite and tridymite in groundmass. Hypersthene-andesite, occurring only at Ishiyama, shows porphyritic and hyaloplitic in texture usually with glass, and consists chiefly of plagioclase (An39–An26 in phenocryst) and hypersthene ($-2V=64°–60°$ in phenocryst). Both minerals are met with in groundmass, usually with cristobalite.

In short, interstitial minerals estimated as products of later crystallization are characterized by a paucity of silica minerals and sometimes by the presence of mica with regard to basalts; on the other hand, by the free silica with regard to andesites. Plagioclase met with in these lavas is rather low in An content and usually surrounded by narrow rims of more sodic plagioclase.

Chemical compositions of the lavas from Volcano Rishiri are presented on a variation diagram (Fig. 2). If one is justified in using the curves as drawn in the figure, the alkali-lime index is about 64. This value is lower than that of Japanese volcanic rocks (65.5) calculated by YAMADA,[8] though it is more calcic than the indices for some provinces in Circum Pacific region (Medicine lake highland: 60.5,[9] Crater Lake: 61.5,[10] Mount Shasta: 63.7,[10] Katmai: 63.8,[11] Lassen Peak: 63.9[10]).

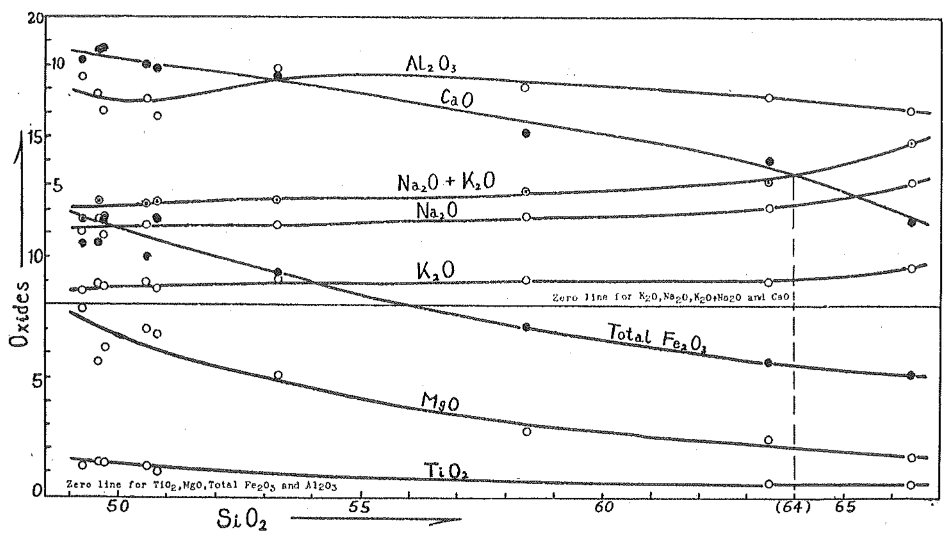


Figure 2. Variation diagram for the lavas from Volcano Rishiri.

The average values of six analyses of basalts and two analyses of augite-hypersthene-andesites from Rishiri are shown in Table III, adding one analysis of hypersthene-andesite. For comparison, average values of Japanese basalt, andesite and rhyolite-andesite calculated by YAMADA[12] and DALY's average values[13] of basalt, andesite and dacite in Europe and America are arranged respectively in the same table.

TABLE III. Average chemical compositions of volcanic rocks.

wt %	1	2	3	4	5	6	7	8	9
SiO_2	50.53	50.9	49.06	60.96	59.8	59.59	66.41	64.6	65.68
TiO_2	1.28	.4	1.36	.56	.2	.77	.55	.3	.57
Al_2O_3	16.99	18.3	15.70	17.00	17.6	17.31	16.20	16.3	16.25
Fe_2O_3	3.57	4.5	5.38	2.59	3.7	3.33	1.98	2.6	2.38
FeO	6.22	6.6	6.37	3.54	3.8	3.13	2.93	3.1	1.90
MnO	.15	.1	.31	.10	.1	.18	.09	.1	.06
MgO	6.46	4.7	6.17	2.61	2.7	2.75	1.55	1.6	1.41
CaO	10.21	10.3	8.95	6.73	6.9	5.80	3.46	5.3	3.46
Na_2O	3.40	2.1	3.11	3.83	2.7	3.58	5.14	2.9	3.97
K_2O	.84	.6	1.52	1.05	1.4	2.04	1.74	1.7	2.67
P_2O_5	.11	.1	.45	.14	.2	.26	.17	.2	.15
H_2O	.63	1.4	1.62	.25	1.2	1.26	.30	1.3	1.50
Total	100.39	100.0	100.00	99.36	100.3	100.00	100.52	100.0	100.00

(1) Average of 6 basalts from Volcano Rishiri.
(2) Average of 29 basalts (less than 55% in silica content) in Japan, (YAMADA)[12].
(3) Average of 198 basalts in Europe, America etc., (DALY)[13].
(4) Average of 2 augite-hypersthene-andesites from Volcano Rishiri.
(5) Average of 57 andesites in Japan (YAMADA)[12].
(6) Average of 87 andesites in Europe, America etc., (DALY)[13].
(7) Hypersthene-andesite from Volcano Rishiri.
(8) Average of 40 rhyolite-andesite rocks (60–70% in silica content) in Japan (YAMADA)[12].
(9) Average of 90 dacites in Europe, America etc., (DALY)[13].

From Table III, the chemical composition of this volcano is characterized by richness in Na_2O and poorness in Fe_2O_3. K_2O and CaO are contained to nearly the same degree as in Japanese effusive rocks. Compared with those of the world, the former is lower, while the latter rather high. The quantity of TiO_2 is nearly the same as that of the world, but larger than that of Japan.

Chemical composition of hypersthene-andesite from Rishiri resembles closely that of DALY's dacite, though different in alkalies. In chemical composition, this lava is comprised in hypersthene-dacite. However this rock is named hypersthene-andesite here, on account of its carrying no quartz.

Consideration on Chemical Composition

Norm- and Niggli-values calculated from Table II are represented in Table IV, and shown in Figures 3–8. In comparison with volcanic rocks from the Nasu and Chôkai volcanic zones which are closely related to Volcano Rishiri from geographical distribution, those of Volcano Tarumai

TABLE IV. Norm- and Niggli-values calculated from Table II.

		1	2	3	4	5	6	7	8	9
Norms										
Q		− 5.5	− 3.6	.0	− 2.1	− 3.1	1.6	12.8	19.8	19.0
Or		3.3	4.9	5.0	5.5	3.3	6.7	6.7	5.5	10.5
Ab		25.6	32.5	23.0	29.4	32.0	29.3	30.4	34.0	43.5
An		33.3	26.1	28.9	27.0	23.8	30.6	27.2	25.3	15.8
Wo		6.7	11.0	10.1	9.0	10.3	7.7	3.6	2.0	0.2
En		22.2	13.4	15.3	18.3	17.7	12.6	6.8	6.4	2.0
Fs		8.9	5.7	7.8	3.8	8.1	6.3	5.9	2.0	3.0
Ap		.3	.3	.3	.3	.3	—	—	.3	.3
Mt		3.7	6.0	5.8	5.8	5.6	5.3	3.5	4.2	3.0
Il		2.3	2.7	2.6	2.4	2.1	—	—	1.1	1.0
Wt%	Or	5.3	7.8	8.9	8.8	5.5	10.0	10.3	8.5	15.0
	Ab	41.8	51.2	40.4	47.5	54.1	44.0	47.2	52.4	62.3
	An	52.9	41.0	50.7	43.7	40.4	46.0	42.5	39.1	22.7
Wt%	Wo	17.9	36.5	30.4	28.9	28.5	28.7	21.9	19.2	2.8
	En	58.7	44.5	46.0	58.8	49.0	47.4	41.6	61.6	54.9
	Fs	23.4	19.0	23.6	12.3	33.5	23.8	36.3	19.2	42.3
Nigglis										
si		108.0	118.6	117.1	119.0	117.8	133.5	185.5	225.2	259.2
al		22.9	23.6	22.4	23.0	21.3	26.7	32.0	33.9	37.2
fm		46.4	38.6	42.9	42.6	44.8	36.4	30.1	28.0	24.5
c		23.4	27.6	27.1	25.1	24.5	26.5	24.6	22.6	14.6
alk		7.3	10.2	7.6	9.3	9.4	10.4	13.3	15.5	23.7
k		.11	.13	.16	.15	.09	.17	.17	.13	.18
mg		.62	.49	.50	.61	.54	.52	.43	.46	.37
al-alk		15.6	13.4	14.8	13.7	11.9	16.3	18.7	18.4	13.5
alk/al-alk		.47	.76	.51	.68	.79	.64	.71	.84	1.75
c-(al-alk)		7.8	14.2	12.3	11.4	12.6	10.2	5.9	4.2	1.1
ti		2.0	2.6	2.5	2.3	1.9	—	—	1.4	1.6
p		.13	.14	.14	.14	.13	—	—	.20	.23
qz		− 21.2	− 22.2	− 13.3	− 18.2	− 19.8	− 8.1	+ 32.3	+ 63.2	+ 64.4

Numbers of each column with reference to Table II.

TABLE V. Chemical compositions and Norm- & Niggli-values of the lavas from Volcano Oshima-ôshima.

wt %	1	2	3	4
SiO_2	48.89	49.90	55.56	61.72
TiO_2	1.02	1.19	.61	.37
Al_2O_3	15.00	16.05	18.28	17.71
Fe_2O_3	2.92	5.03	2.46	1.12
FeO	6.41	5.55	5.11	4.33
MnO	.25	.14	.19	.10
MgO	10.60	7.03	4.05	1.83
CaO	10.91	10.51	8.57	5.19
Na_2O	1.95	2.15	2.67	3.21
K_2O	1.13	1.92	1.80	3.28
P_2O_5	.05	.23	.22	.20
$H_2O(+)$	.64	.26	.62	.83
$H_2O(-)$	.12	.06	.13	.16
Total	99.89	99.92	100.27	100.05
Norms				
Q	− 4.4	− .7	+ 8.3	+ 14.1
Or	6.7	11.1	10.6	19.5
Ab	16.8	18.3	22.5	27.3
An	28.6	27.6	32.5	24.2
Wo	10.7	9.3	3.5	.3
En	26.5	17.6	10.1	4.6
Fs	8.2	4.4	6.9	5.7
Mt	4.2	7.2	3.5	1.6
Il	2.0	2.3	1.2	.8
Ap	.0	.7	.7	.5
wt% Or	12.8	19.5	16.2	27.4
wt% Ab	32.2	32.1	34.3	38.4
wt% An	45.0	48.4	49.5	44.2
wt% Wo	23.1	29.7	17.1	2.8
wt% En	59.3	56.2	49.2	43.4
wt% Fs	17.6	14.1	33.7	43.8
Nigglis				
si	104.5	116.0	154.6	216.6
al	18.8	22.0	29.9	36.6
fm	50.5	44.1	34.2	25.4
c	25.0	26.2	25.5	19.5
alk	5.7	7.7	10.4	18.5
k	.27	.36	.31	.40
mg	.66	.55	.49	.38
al-alk	13.1	14.3	19.5	18.1
alk/al-alk	.43	.54	.53	1.02
c-(al-alk)	11.9	11.9	6.0	1.4
ti	1.6	2.0	1.3	1.0
p	.0	.3	.3	.2
qz	− 18.3	− 14.8	+ 12.6	+ 43.0

(1) Somma lava of Nishiyama (Augite-olivine-basalt), Yamasedomari.
(2) Central cone lava of Nishiyama (Olivine-augite-basalt), Yakekuzure peninsula.
(3) Somma lava of Nishiyama (Olivine & reddish brown hornblende bg. augite-hypersthene-andesite), Aidomari.

(4) Lower Higashiyama lava (Reddish brown hornblende-augite-hypersthene-andesite). Aidomari.

The writer's analysis was done on the rock specimens collected by Mr. M. TAKAYASU to whom heartly thanks on here by expressed for his kindly offering the specimens for free use.

and others belonging to the Nasu zone and of Volcano Oshima-ôshima belonging to the Chôkai zone were selected, of which the former is quoted from ISHIKAWA's paper,[7] and the latter given by the writer (Table V).

Norm

For convenience, insufficient silica of undersaturated rocks are represented as negative Q. Most of the basalts from the Volcanoes Rishiri and Oshima-ôshima are deficient in Q. This fact coincides with their lacking silica minerals and carrying a fair amount of olivine in mode. In andesites, normative Q is calculated somewhat high, but lower than those of the average values of Japanese andesites.

Normative feldspar of Rishiri, as seen in Figure 3, is characterized by low values in An and Or. Normative An of augite-hypersthene-andesites (SiO_2=56.50–60.80%) from Tarumai is higher than those of basalts from Rishiri, regardless of their silica contents. This relation is well represented by modal feldspars; that is plagioclase of Tarumai lava is very calcic, sometimes including large anorthite crystals in the dome lava of this volcano; on the contrary, that of Rishiri is very sodic and usually surrounded by a narrow rim of more sodic plagioclase. Normative feldspar of Oshima-ôshima is very high in Or. This Or molecule seems to depend upon modal potash feldspar in groundmass as already reported by KUNO.[14]

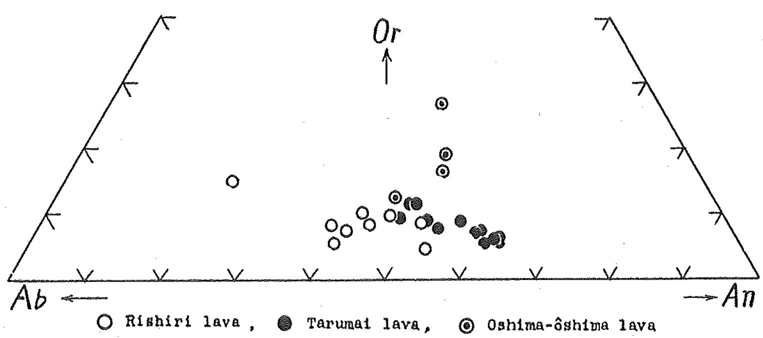
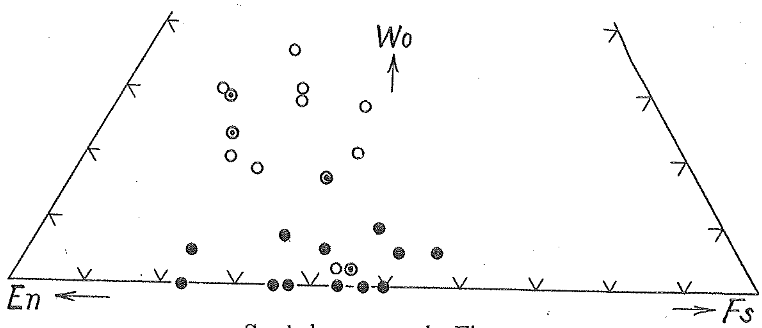


Figure 3. Diagram showing Norm feldspar.

Normative pyroxene of Rishiri is rather high in Wo, except hypersthene-andesite which is extremely low. Oshima-ôshima resembles that of Rishiri, while Tarumai is far lower in Wo, and C is sometimes calculated.



Symbols same as in Figure 3

Figure 4. Diagram showing Norm pyroxene.

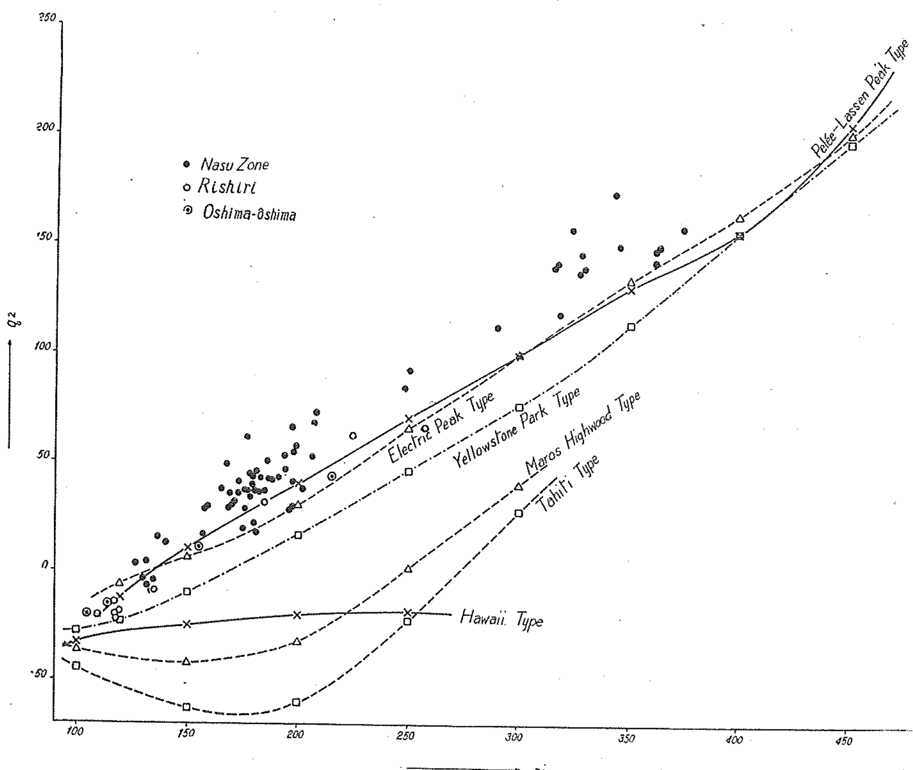


Figure 5. Diagram showing *qz* values.

Niggli

As seen in Figure 5, Niggli-*qz* of Rishiri and Oshima-ôshima are lower than that of the Nasu zone, as is expected from low values of normative Q.

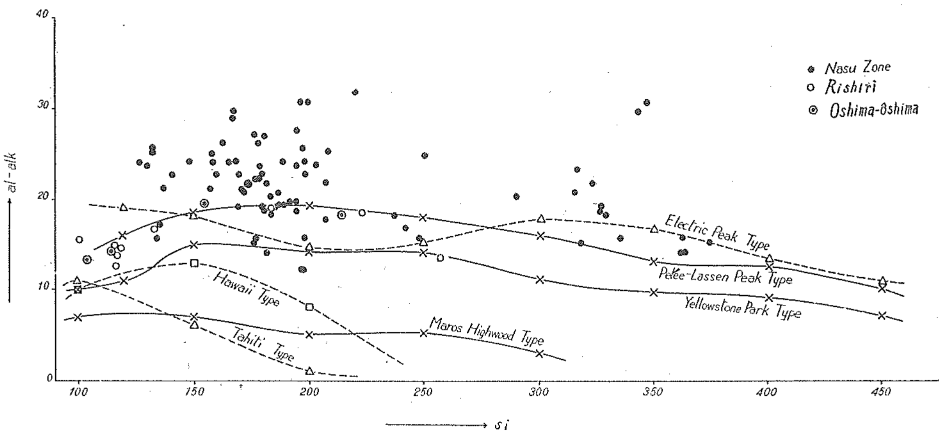


Figure 6. Diagram showing *al-alk* values.

In *al-alk* (Fig. 6) also, Rishiri and Oshima-ôshima are lower than the Nasu zone Volcanoes and on the contrary, are rather higher in *c-(al-alk)* (Fig. 7).

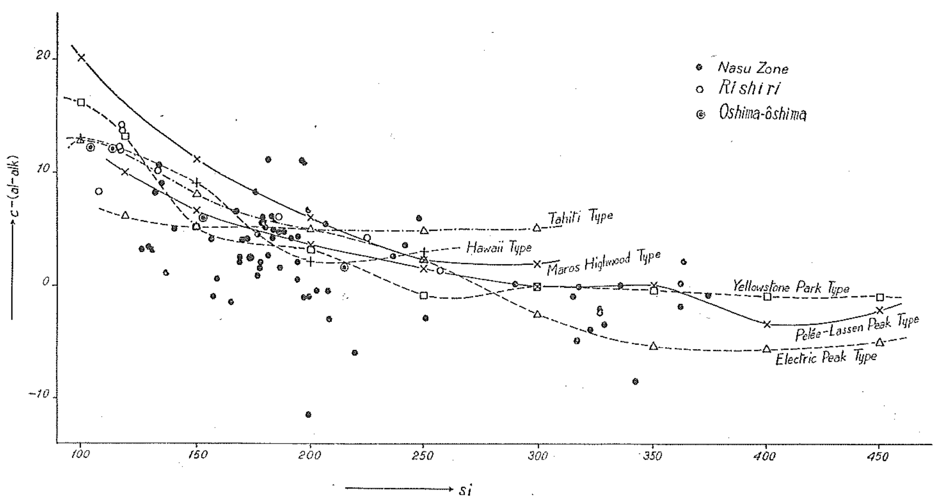


Figure 7. Diagram showing *c-(al-alk)* values.

As for *k-mg* ratio (Fig. 8), Rishiri shows low value in *k*, but high value in *mg*. Oshima-ôshima is also high in *mg*, but extremely rich in *k*, in contrast to the poorness in *k* of Rishiri. This relation coincides with their mode and norms.

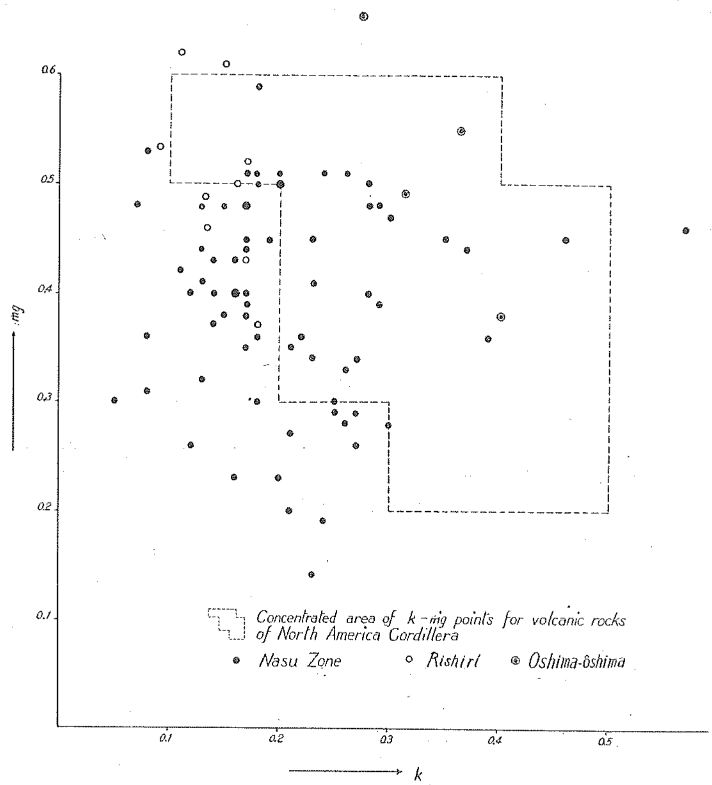


Figure 8. Diagram showing *mg-k* relation.

Summary

From the above description, it is concluded that the chemical compositions of the lavas from Volcano Rishiri are closely related to modal mineral compositions and characterized by their being rich in Na_2O, while comparatively poor in SiO_2, compared with those of the Nasu volcanic zone including Volcano Tarumai. Alkali-lime index of the Rishiri lava is estimated about 64, which indicates that it is more alkalic than the index of Japanese volcanic rocks.

The chemical compositions of the lavas from Volcano Oshima-ôshima differ in alkalies from those of Rishiri; that is, the former is rich in K_2O and also high in Or and k, while the latter is rich in Na_2O and low in Or, An and k, though they contain nearly the same amount of total alkalies. Volcano Kanpû at 'Oga peninsula, Aikta prefecture, belonging to the Chôkai volcanic zone, is also high in alkalies (alkali-lime index was estimated 60 by TANEDA),[15] but its K_2O[16-18] is somewhat higher than that of Rishiri.

In the light of the chemical chracters outlined above, it may be supposed that the volcanic zone to which Volcano Rishiri belongs is independent of the Nasu zone, as already suggested by AKAGI[6] from tectonic stand-point. But this supposition must be dependent upon further investigations including petrographical and chemical studies on the lavas from Volcanoes of Syokanbetsu in Hokkaido and Kamabuse in Saghalien etc., belonging to the Rishiri volcanic zone.

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