PRELIMINARY NOTE ON ALKALINE RHYOLITES FROM TOKATI, HOKKAIDO

By

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With 4 Plates and 6 Text-Figures

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INTRODUCTION

In the course of a geological study of Tokati Plain, Hokkaido, in 1931–1932, the writer found two kinds of alkaline rhyolites: first, aegirine-augite hyalo-rhyolite, ôkawaite, which develops in the environs of the upper course of the river Ôkawa running through Toyokoro Village, and second, comendite, which occurs at Maru-yama and its vicinity near Tyurui, Tokati Province. Rocks which possess an alkaline nature are very rare in this country and their occurrence as hitherto known is limited to a few places in southwestern and central Japan. It will, therefore, be of more than usual interest to give a petrographic note on these alkaline rocks which are the first appearance in northern Japan, especially in Hokkaido. Petrographic descriptions of these rocks have been separately reported, in papers written in Japanese[1] and briefly in English [2] during the progress of work upon these rocks. The present paper has been prepared with a view towards setting forth the results obtained to date upon both the alkaline rhyolites now being investigated.

(1) T. NEMOTO: Soda-trachytic Rock from Toyokoro, Hokkaido. Jour. Japanese Assoc. Min. Petro. and Econ. Geol., Vol. IX, 1933, pp. 105–110.
T. NEMOTO: Glassy Soda-rhyolite from Tokati, Hokkaido. Jour. Japanese Assoc. Min. Petro. and Econ. Geol., Vol. X, 1933, pp. 46–53, 99–107.
(2) T. NEMOTO: Aegirine-augite Hyalo-rhyolite from Tokachi, Hokkaido. Proc. Imp. Acad., Vol. X, 1934, pp. 21–24.

PART I.

AEGIRINE-AUGITE HYALO-RHYOLITE, ÔKAWAITE.

I. GEOLOGICAL SKETCH

The geological features of the environs of the area in which aegirine-augite hyalo-rhyolite develops have already been reported

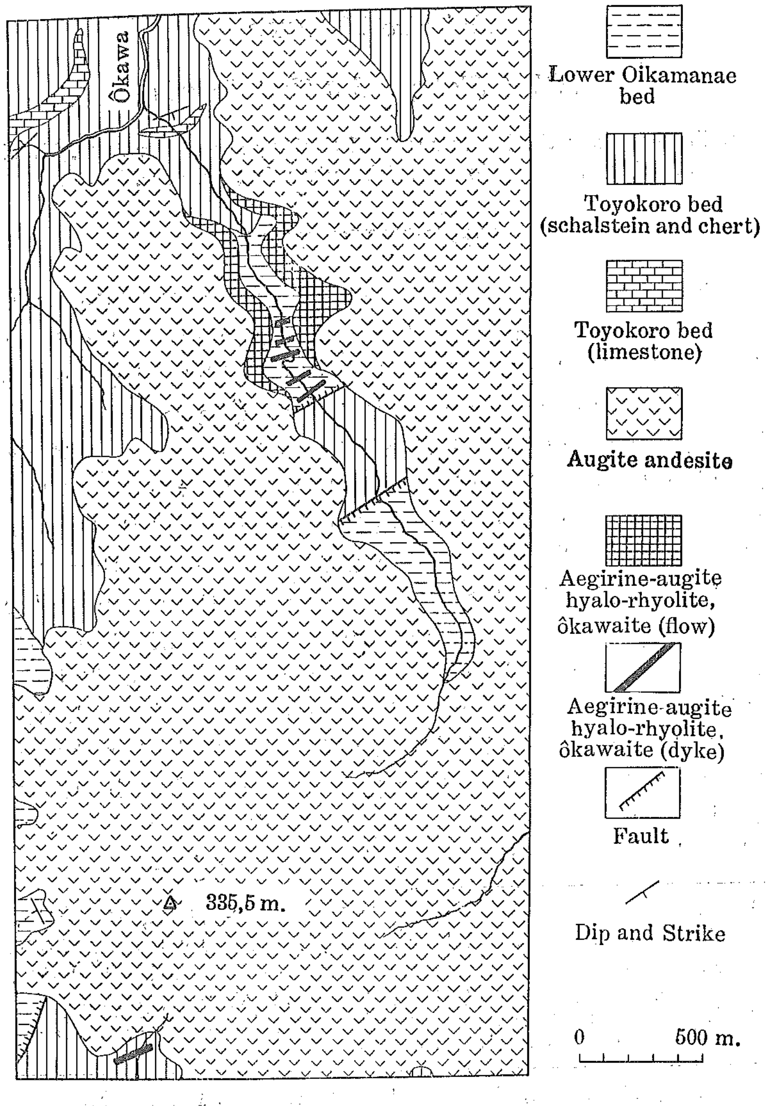

Fig. 1. Geological Map of the Environs of the ÔKAWA.

in papers published in Japanese(1). Here the writer is concerned only with the facts of the distribution and occurrence of the rock which have been ascertained up to the present. As is seen in Fig. 1, aegirine-augite hyalo-rhyolite, which develops in the upper course of the Ôkawa as well as in a small tributary flowing to the south, occurs partly as dykes intruded into the Neogene sediments, known in this region as lower Oikamanae bed, and into the Toyokoro bed, a so-called Palaeozoic formation, and partly as a flow lying unconformably upon the lower Oikamanae bed and Toyokoro bed, as shown in Pl. XLII, Fig. 1.

The pebble of the rock is also often found in several tributaries in the region. The outcrops from which the pebbles were derived, however, have not been found. It may be anticipated, therefore, that the knowledge of the distribution will be extended by further geological study which the writer intends to carry out in the future.

II. PETROGRAPHY

1. Macroscopical Character

In the specimen at hand, the rock is seen to be of a vitreous texture and is dark gray in colour, with a greenish tone. In appearance it is not unlike pitchstone, but it is abundant in porphyritic anorthoclase, 1–3 mm in length. In addition to the dark colour of the glassy basis, porphyritic aegirine-augite is so small in quantity and so scarce that the mineral is not easily recognizable.

2. Microscopical Character

Under the microscope, the rock shows a hypocrystalline prophyritic texture. As shown in Pl. XLIV, Fig. 1, the phenocryst is composed essentially of anorthoclase and aegirine-augite, to which is often added a small amount of granular mineral recognized to be a pseudomorph after leucite. The groundmass, which consists mainly of glass, shows a typical perlitic texture in some parts of the rock, as shown in Pl. XLIV, Figs. 1, 3 and 4.

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(1) T. Nemoto, S. Ôishi and T. Watanabe: The Explanatory Text of the Geological Map of Hokkaido; Obihiro Sheet, Scale 1:100,000. Rep. Geol. Comm. Hokkaido, No. 2, 1933, pp. 1–20.

Anorthoclase, which is the most dominant phenocryst, is euhedral or subhedral, and usually shows a rectangular and wedge-shaped cross-section, as illustrated in Pl. XLIV, Figs. 1 and 2. It is generally a tabular crystal parallel to (010): some are short rectangular prisms elongated along the a-axis. The crystallographic faces observed are b(010), c(001), m(110), n(021) and y($\bar{2}$01). Cleavage is usually perfect, and those parallel to (010) and (001) are distinguishable. Carlsbad twinning is common. Albite twinning is so rare that it is only observed once or twice in several sections. The fine microscopic lamellar twinning according to the combination of the albite and microcline laws rarely occurs. The optical properties measured by a universal stage are as follows:

$$\begin{array}{lll} \text{optical plane} \wedge & (010) = & 85^\circ - 89^\circ \\ a \wedge X' \quad \text{on} & (010) = & 6^\circ - 12^\circ \\ a \wedge X' \quad \text{on} & (001) = & 2^\circ - 6^\circ \\ (-)\ 2V & = & 36^\circ - 44^\circ \end{array}$$

The refractive indices determined by the immersion method are given below.

$$\alpha' = 1.522$$
$$\gamma' = 1.529$$

From the fact that the above optical constants varying to some extent, it may be considered that the chemical composition of the mineral—the ratio of orthoclase to albite—is not similar in all crystals. It often encloses aegirine-augite, of which a description follows.

Aegirine-augite, which follows the anorthoclase in amount and is scattered in all parts of the rock, is usually euhedral and shows a prismatic crystal, 1.5 mm in maximum length, as shown in Pl. XLIV, Figs. 1 and 3. Cleavage parallel to (110) is dominant. The twinning and zonal structure is rarely observed. It is strongly pleochroic with X=grass green, Y=light grass green, Z=yellowish green. Absorption is strong, $X > Y > Z$. The optical characters measured by a universal stage are given below.

$$(+)\,2V = 65^\circ \pm 1^\circ$$
$$c \wedge X = 44^\circ$$

It is often enclosed in anorthoclase, and often penetrates it. It may be considered, therefore, that the crystallization of aegirine-augite has been completed earlier than that of anorthoclase.

The granular mineral, which is recognized to be a pseudomorph after leucite, usually shows a rounded form, 0.5 mm in maximum diameter, as illustrated in Pl. XLIV, Figs. 1 and 4. Because of its rounded outline and the regular arrangement of the inclusions in it, it is considered that the original mineral, leucite, has been replaced by a colourless mineral, natrolite, which shows a spherulitic texture and has a lower refractive index than that of Canada balsam.

As illustrated in the work of G. W. MOREY and N. L. BOWEN(1), leucite is temporarily able to crystallize out of a more acidic liquid than orthoclase prior to its crystallization. From the evidence that leucite is often included in anorthoclase and often penetrates it, it may be concluded that the crystallization of leucite had been completed earlier than that of anorthoclase. It is not impossible, therefore, to suppose that leucite which has been transformed into natrolite by reaction with residual magma had separated as a temporary product from magma, whose composition is rich in alkali.

Magnetite, which occurs as an accessory mineral, is present in a slightly smaller amount, forming small crystals of irregular shape. It is related in occurrence to aegirine-augite, being found mainly in the mineral and rarely in the glassy groundmass.

3. Chemical Character

The rock is so fresh that the phenocrysts and the groundmass are always free of alteration products, and it is therefore considered to be the best sample for chemical analysis. In the glassy groundmass, however, it often encloses andesitic and basaltic xenoliths, 1–2 mm in length. The xenolith is so small and is so uniformly scattered in all parts of the basis that it is unable to separate completely from the glassy basis. The amount of the xenolith which has been determined by the Rosiwal method of three thin sections is 1.05% by volume, as given in Table IX. It is considered, therefore, that the existence of the xenolith is not so effective in the chemical composition of the rock.

A chemical analysis was twice carefully made by the writer. The mean value of the double analyses is given in Table I together with the norm.

(1) G. W. MOREY and N. L. BOWEN: The Melting of Potash Feldspar. Am. Jour. Sci., (5), Vol. IV, 1922, pp. 1–21.

TABLE I.

Wt. %		Norm		Ratio
SiO_2	66.25	Q	29.52	$\frac{\text{Sal}}{\text{Fem}} = 16.18$
TiO_2	0.26	Or	15.01	
Al_2O_3	12.89	Ab	34.06	$\frac{Q}{F} = 0.53$
Fe_2O_3	2.09	An	6.39	
FeO	1.37	C	1.12	
MnO	0.03	Hy	1.50	
MgO	0.42	Mt	3.02	$\frac{K_2O' + Na_2O'}{CaO'} = 4.00$
CaO	1.29	Il	0.46	
Na_2O	4.04	Ap	0.34	$\frac{K_2O'}{Na_2O'} = 0.42$
K_2O	2.53			
P_2O_5	0.07			
H_2O+	6.08			I, (3) 4, 2, 4
H_2O-	2.46			Lassenose
Total	99.78			

In order to discuss the chemical characteristics of the rock, the chemical composition of the rock as well as the mean chemical compositions of rocks in the rhyolite family are quoted in Table II.

TABLE II.

	I	II	III	IV	V
SiO_2	72.60	70.19	66.25	74.44	68.63
TiO_2	0.30	0.07	0.26	0.19	0.35
Al_2O_3	13.88	12.37	12.89	11.27	10.30
Fe_2O_3	1.43	1.45	2.09	2.78	5.60
FeO	0.82	0.81	1.37	0.94	2.61
MnO	0.12	0.02	0.03	0.08	0.21
MgO	0.38	0.91	0.42	0.35	0.37
CaO	1.32	1.43	1.29	0.21	1.07
Na_2O	3.54	3.03	4.04	4.18	6.14
K_2O	4.03	3.57	2.53	4.95	4.17
P_2O_5	0.06	0.03	0.07	0.02	0.02
H_2O + H_2O −	1.52	6.48	6.08 2.46	0.59	0.53
Total	100.00	100.36	99.78	100.00	100.00

I. Rhyolite, average of 64 analyses(1).
II. Pitchstone, average of 18 analyses(2).
III. Aegirine-augite hyalo-rhyolite, ôkawaite.
IV. Comendite, average of 6 analyses(3).
V. Pantellerite, average of 12 analyses(4).

(1) R. A. DALY: Igneous Rocks and Their Origin, 1914, p. 19.
(2) A. JOHANNSEN: A Descriptive Petrography of the Igneous Rocks, Vol. II, 1932, p. 281.
(3) R. A. DALY: ibid., p. 20.
(4) R. A. DALY: ibid., p. 22.

The water contained in a glassy rock plays a important part in any petrogenetic consideration. In the present paper, however, the writer intends merely to discuss the chemical character. Hence the mean chemical compositions of the rhyolite family are recalculated to 100%, eliminating with water which is not so important in the main composition of magma. The result is tabulated as follows:

TABLE III.

	I	II	III	IV	V
SiO_2	73.72	74.77	72.61	74.88	69.00
TiO_2	0.30	0.08	0.29	0.19	0.35
Al_2O_3	14.10	13.18	14.13	11.34	10.36
Fe_2O_3	1.45	1.54	2.29	2.80	5.63
FeO	0.83	0.86	1.50	0.95	2.62
MnO	0.12	0.02	0.03	0.08	0.21
MgO	0.40	0.97	0.46	0.35	0.37
CaO	1,34	1.52	1.41	0.21	1.08
Na_2O	3.59	3.23	4.43	4.20	6.17
K_2O	4.09	3.80	2.77	4.98	4.19
P_2O_5	0.06	0.03	0.08	0.02	0.02
Total	100.00	100.00	100.00	100.00	100.00

I. Rhyolite. II. Pitchstone.
III. Aegirine-augite hyalo-rhyolite, ôkawaite.
IV. Comendite. V. Pantellerite.

From the above table, the molecular numbers of the important components, as well as the values of Na_2O+K_2O, and $Al_2O_3-(Na_2O+K_2O)$, which are conveniently multiplied by 1000, are obtained as follows:

TABLE IV.

	I	II	III	IV	V
SiO_2	1229	1246	1210	1248	1150
Al_2O_3	138	129	139	111	102
Na_2O	58	52	72	68	100
K_2O	44	40	30	53	45
$Na_2O + K_2O$	102	92	102	121	145
$Al_2O_3 - (Na_2O + K_2O)$	36	37	37	−10	−43
CaO	24	27	25	4	19
Fe_2O_3	9	10	14	18	35
FeO	12	12	21	13	36

I. Rhyolite. II. Pitchstone.
III. Aegirine-augite hyalo-rhyolite, ôkawaite.
IV. Comendite. IV. Pantellerite.

As shown in Tables II, III and IV, the chemical composition of this rock is somewhat similar to that of pitchstone in containing a great amount of H_2O. Moreover, it is like rhyolite in having a high percentage of Al_2O_3 and CaO, and a small amount of total alkalies. The chemical composition of the rock is consequently very different from that suggested by its mineralogical composition.

To discuss the chemical characteristics between alkaline and calc-alkaline rock, both the relationships of Na_2O/K_2O to total alkalies and of Fe_2O_3+FeO to Na_2O must be examined, in addition to a comparison with molecules of Al_2O_3, Na_2+K_2O and CaO. This is because the molecular relation between Al_2O_3, Na_2O+K_2O and CaO merely shows whether a rock under consideration belongs to an alkaline or a calc-alkaline rock, and, further, whether alkali and lime feldspars, as well as sodic coloured mineral, are contained or not. On the contrary, the relationship of Na_2O/K_2O to total alkalies denotes that a rock is rich in Na_2O or K_2O, in addition to whether the rock belongs to an alkaline or a calc-alkaline rock, and that of Fe_2O_3+FeO to Na_2O indicates whether the amount of sodic coloured mineral contained in the rock is much or little. The amounts of Fe_2O_3 and FeO are controlled by the amount of magnetite contained in the rock. In the case of basic rock, which is usually rich in magnetite, therefore, it is not possible to estimate the amount of sodic coloured mineral from the relation of Fe_2O_3+FeO to Na_2O. In the case of acidic rock, in which a very small amount of magnetite is contained, however, it is possible to gauge the amount of sodic coloured mineral from the above relationship.

From Table IV, the values of Na_2O+K_2O, Na_2O/K_2O, Na_2O, and Fe_2O_3+FeO are quoted in Table V. To show more clearly these chemical relations, Figs. 2 and 3 are given below.

TABLE V.

	I	II	III	IV	V
$Na_2O + K_2O$	102.	92.	102.	121.	145.
$\frac{Na_2O}{K_2O}$	1.32	1.30	2.40	1.28	2.22
Na_2O	58.	52.	72.	68.	100.
$Fe_2O_3 + FeO$	21.	22.	35.	31.	71.

I. Rhyolite. II. Pitchstone.
III. Aegirine-augite hyalo-rhyolite, ôkawaite.
IV. Comendite. IV. Pantellerite.

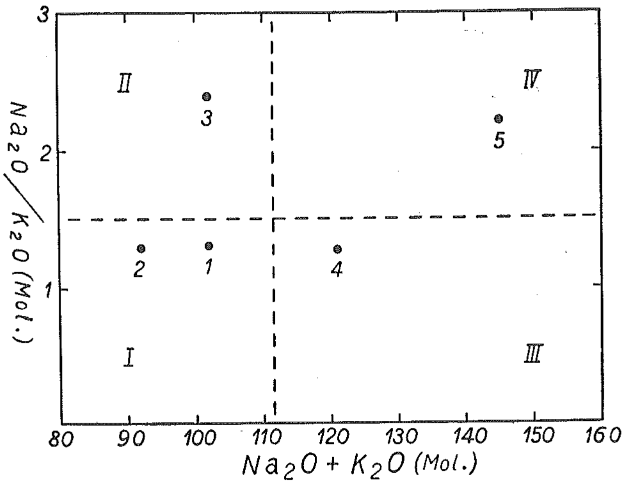

Fig. 2.

1. Rhyolite. 2. Pitchstone.
3. Aegirine-augite hyalo-rhyolite, ôkawaite.
4. Comendite. 5. Pantellerite.

In Fig. 2, the ordinate is divided into two parts by the value of $Na_2O/K_2O=1.51$, which corresponds to equal values of Na_2O and K_2O in weight percentage, and the abscissa is divided by the value of $Na_2O+K_2O=111.5$, which is the mean value of the total alkalies of rhyolites and comendites. From these divisions, Fig. 2 may be divided into four different fields, in which I, II, III and IV are enumerated, and each field can be taken as the region representing rhyolite, soda-rhyolite, potash-rich alkaline rhyolite (comendite) and soda-rich alkaline rhyolite (pantellerite). From Fig. 3, it is also known that the parallel increase of Na_2O and Fe_2O_3+FeO may indicate the increment of sodic coloured minerals in the rock.

As above stated, the rock is identical with pitchstone in containing a great amount of H_2O, and with rhyolite in having a large percentage of Al_2O_3 and CaO. In the value of Na_2O+K_2O, however, the rock representing Field II in Fig. 2 is nearly like rhyolite and pitchstone, which occupy Field I, being low in alkali feldspar and sodic coloured mineral, but in the ratio of Na_2O/K_2O it is far greater than rhyolite, representing that the alkali feldspar is of the sodic variety, anorthoclase, as in the case of pantellerite, which occupies Field IV. From the relation of Fe_2O_3+FeO to Na_2O, it is obvious that the rock is not so abundant in sodic coloured mineral as in the

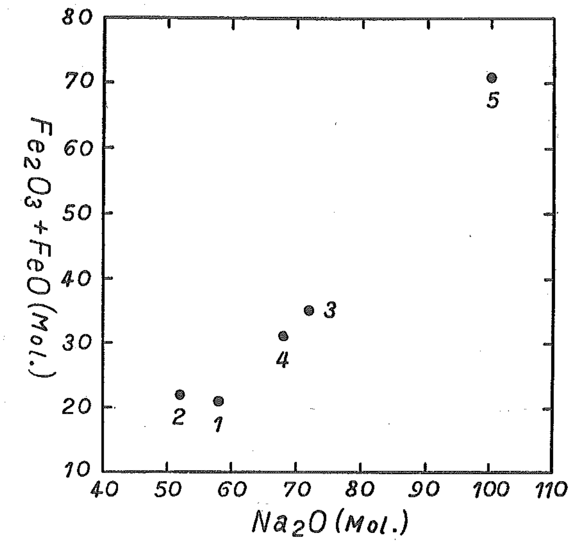

Fig. 3.

1. Rhyolite. 1. Pitchstone.
3. Aegirine-augite hyalo-rhyolite, ôkawaite.
4. Comendite. 5. Pantellerite.

case of pantellerite, but it is richer than rhyolite and pitchstone, showing the nearest analogy with comendite.

L. HAWKES and H. F. HARWOOD(1) have recently described an anorthoclase-bearing glassy contact facies of a felsite dyke occurring in the valley of Jafnadal, Stodvarfjord, in east Iceland. Though the glassy contact facies is nearly similar to the rock under consideration in having anorthoclase and slightly sodic pyroxene as phenocryst, and in consisting of a hydrous glass basis, the groundmass of the former, being composed of glass crowded with microlites in fluxion parallelism, contrasts with that of the latter, which consists of glass with no microlite. Moreover, as shown in Tables VI, VII, VIII and IX, the glassy rock is not analogous to the rock in chemical composition and in the volume percentage of phenocrysts which is, in the latter, the mean value of the results obtained from three sections by the Rosiwal method. Rather the former is higher in Na_2O and lower in sodic coloured mineral than the latter.

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(1) L. HAWKES and H. F. HARWOOD: On the Changed Composition of an Anorthoclase-bearing Rock-glass. Min. Mag., Vol. XXIII, 1932, pp. 163–174.

TABLE VI.

	I	II	Ia	IIa
SiO_2	66.25	70.55	72.61	76.19
TiO_2	0.26	0.09	0.29	0.10
Al_2O_3	12.89	11.82	14.13	12.76
Fe_2O_3	2.09	0.55	2.29	0.59
FeO	1.37	1.06	1.50	1.14
MnO	0.03	0.04	0.03	0.04
MgO	0.42	0.03	0.46	0.03
CaO	1.29	0.74	1.41	0.80
Na_2O	4.04	5.08	4.43	5.49
K_2O	2.53	2.58	2.77	2.78
P_2O_5	0.07	tr.	0.08	—
H_2O +	6.08	5.88	—	—
H_2O −	2.46	1.40	—	—
CO_2	n. d.	0.03	—	0.03
Cl	n. d.	tr.	—	—
S	n. d.	tr.	—	—
SrO	n. d.	tr.	—	—
BaO	n. d.	0.03	—	0.03
Li_2O	n. d.	none	—	—
NiO	n. d.	none	—	—
F	n. d.	0.04	—	0.04
		99.92		100.02
O less F		0.02		0.02
Total	99.78	99.90	100.00	100.00

I. Aegirine-augite hyalo-rhyolite, ôkawaite. T. NEMOTO, analyst.

II. Anorthoclase-bearing glassy contact facies of a felsite dike. Jafnadal, Stodvarfjord, Iceland. H. F. HARWOOD, analyst.

Ia. Analysis No. I recalculated to 100%, with water eliminated.

IIa. Analysis No. II recalculated to 100%, with water eliminated.

TABLE VII.

	I	II
SiO_2	1210	1270
Al_2O_3	139	125
Na_2O	72	89
K_2O	30	30
$Na_2O + K_2O$	102	119
$Al_2O_3 - (Na_2O + K_2O)$	37	6
CaO	25	14
Fe_2O_3	14	4
FeO	21	16

I. Aegirine-augite hyalo-rhyolite, ôkawaite.
II. Anorthoclase-bearing glassy contact facies of a felsite dike.

TABLE VIII.

	I	II
$Na_2O + K_2O$	102.	119.
$\frac{Na_2O}{K_2O}$	2.40	2.97
Na_2O	72.	89.
$Fe_2O_3 + FeO$	35.	20.

I. Aegirine-augite hyalo-rhyolite, ôkawaite.
II. Anorthoclase-bearing glassy contact facies of a felsite dike.

TABLE IX.

	II	II
Glass	67.92	—
Anorthoclase	28.76	2.8
Aegirine-augite	1.48	0.05*
Pseudomorph after leucite	0.56	—
Magnetite	0.23	—
Xenolith	1.05	—
Total	100.00	

* It indicates the value of a slightly sodic pyroxene.
I. Aegirine-augite hyalo-rhyolite, ôkawaite.
II. Anorthoclase-bearing glassy contact facies of a felsite dike.

4. Summary

All the evidence cited—mineralogical and chemical—may be enumerated as follows:

1. The phenocryst is composed essentially of anorthoclase and aegirine-augite, which are the characteristic minerals of alkaline rhyolite, and lacks entirely plagioclase and some coloured minerals which are low in alkali and rich in CaO and MgO.

2. The rock is nearly identical with pitchstone in having a groundmass which consists only of hydrous glass.

3. It is like rhyolite in having a large percentage of Al_2O_3 and CaO, and a small amount of total alkalies.

4. The value of Na_2O/K_2O, which is 2.40 by molecules is slightly greater than that of pantellerite. In the relation of Na_2O/K_2O to Na_2O+K_2O, it occupies Field II in Fig. 2.

5. From the relation of Fe_2O_3+FeO to Na_2O, the rock seems to be slightly richer in sodic coloured mineral than comendite.

As above described, although the rock may be considered a typical alkaline rock from its mineralogical composition, it cannot from its chemical character be denominated a typical one. Moreover, in the alkaline rhyolite(1) which has been referred to by the writer,

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(1) H. FÖRSTNER: Über die Feldspäthe von Pantelleria. Zeitschr. f. Kryst., Bd. VIII, 1883, SS. 125–202.

H. S. WASHINGTON: Igneous Rocks from Eastern Siberia. Am. Jour. Sci., [4], Vol. XIII, 1902, p. 180.

A. OSANN: Beiträge zur chemischen Petrographie, II Teil, Analysen der Eruptivgesteine aus den Jahren 1884–1900, 1905, S. 123.

F. W. CLARKE: Analyses of Rocks and Minerals from the Laboratory of the United States Geological Survey, 1880–1908. U. S. G. S., Bull. 419, 1910, p. 42.

A. JOHNSEN: Zur Petrographie der Inseln S. Pietro und S. Antioco (Sardinien). Centr. f. Min., 1912, S. 738.

M. GOLDSCHLAG: Beiträge zur Kenntnis der Geologie und Petrographie Ostafrikas: II. Petrographisch-chemische Untersuchung einiger jungvulkanischen Gesteine aus der Umgebung des Victoriasees, besonders längs der Uganda-Eisenbahn. Centr. f. Min., 1912, S. 588.

S. KÔZU: Petrological Notes on the Igneous Rocks of the Oki Islands. Sci. Rep. Tohoku Imp. Univ., Ser. 2, Vol. I, 1913, pp. 37–40.

H. S. WASHINGTON: The Volcanoes and Rocks of Pantelleria. Jour. Geol., Vol. XXI, 1913, pp. 697–706; Vol. XXII, 1914, p. 17.

H. S. WASHINGTON: Chemical Analyses of Igneous Rocks. U. S. G. S., Prof. PAP. 99, 1917.

R. REINISCH: Petrographishes Praktikum, II Teil, 1920, S. 103.

glass composing groundmass usually contains a small amount of water, as in the case of all obsidian, with the exception of aegirite-pantellerite-pumice from the Island of Pantelleria(1), which contains 3.15% as $H_2O(+)$, and 0.49% as $H_2O(-)$. But the groundmass of the rock contains a far greater amount of H_2O, 6.08% as $H_2O(+)$ and 2.46% as $H_2O(-)$, than aegirite-pantellerite-pumice. The writer, therefore, wishes to classify the rock as an aegirine-augite hyalo-rhyolite having character intermediate between rhyolite and alkaline-rhyolite in mineralogical and chemical composition, and wishes to propose giving it a new name "ôkawaite" derived from its locality, the Ôkawa.

PART II.

COMENDITE

I. GEOLOGICAL SKETCH

The geological feature of the environs of the region in which comendite develops has already been described, in a paper written in Japanese(2). Here the writer is only concerned with the distribu-

(1) H. S. WASHINGTON: The Volcanoes and Rocks of Pantelleria. Jour. Geol., Vol. XXI, 1913, p. 703.

(2) T. NEMOTO and Y. SASA: The Explanatory Text of the Geological Map of Hokkaido; Taiki Sheet, Scale 1:100,000. Rep. Geol. Comm. Hokkaido, No. 3, 1933, pp. 1–36.

S. KÔZU and K. SETO: On the Alkali-Rocks from Korea (in Japanese). Jour. Geol. Soc. Tokyo, Vol. XXIX, 1922, pp. 214–218.

H. ROSENBUSCH – A. OSANN: Elemente der Gesteinslehre, 1923, S. 366.

S. KÔZU and K. SETO: Some Alkali-rocks occurring in Korea. Proc. 3rd Pan-Pacific Sci. Cong. Tokyo, 1926, Vol. I, p. 781.

F. H. HATCH and A. K. WELLS: The Petrology of the Igneous Rocks, 1926, p. 275.

A. LACROIX: Les rhyolites et les trachytes hyperalcalins quartzifères, à propos de ceux de la Corée. Comp. Rend. Ac. Sci., t. 185, 1927, pp. 1410–1415.

F. YAMANARI: On the Hakutoite (in Japanese). Jour. Geol. Soc. Tokyo, Vol. XXXIV, 1927, p. 474.

T. TOMITA: Geological and Petrological Study of Dôgo, Oki, Part III (in Japanese). Jour. Geol. Soc. Tokyo, Vol. XXXV, 1928, p. 478.

W. C. SMITH: A Classification of some Rhyolites, Trachytes, and Phonolites from part of Kenya Colony, with a Note on some Associated Basaltic Rocks. Q. J. G. S. London, Vol. LXXXVII, 1931, p. 219.

A. JOHANNSEN: A Descriptive Petrography of the Igneous Rocks, Vol. II, 1932, p. 68.

tion and the occurrence of the rock known up to the present. As shown in Fig. 4, comendite, which is distributed at Maru-yama and in its vicinity, occurs as dykes intruded into the lower Oikamanae bed, which are composed mainly of sandstone and tufaceous rocks.

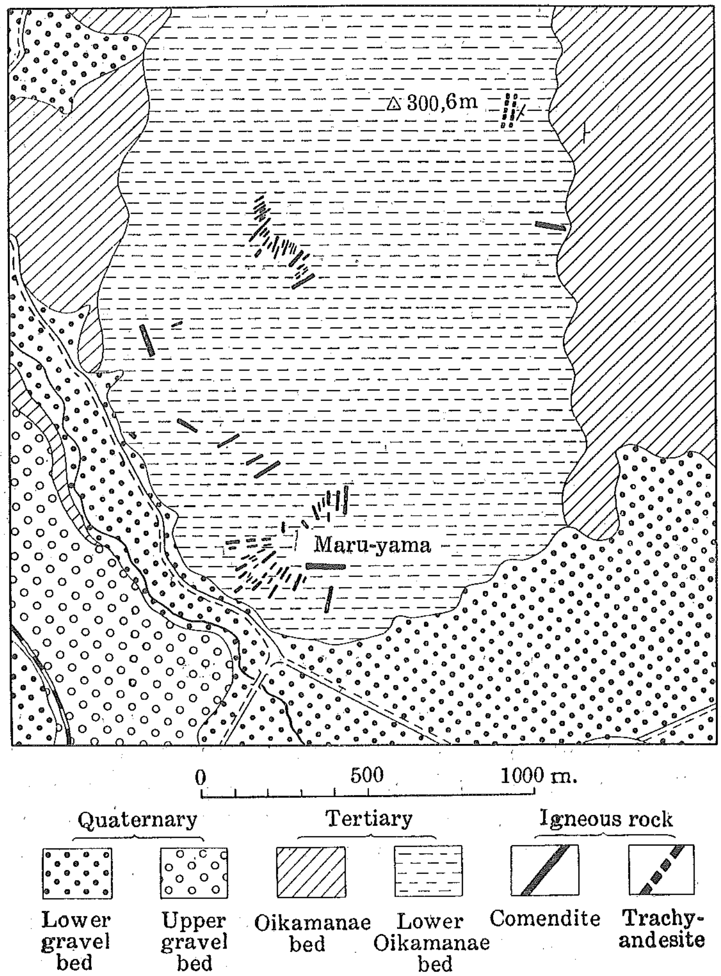

Fig. 4. Geological Map of the Environs of Maru-yama.

Maru-yama on which many dykes of the rock develop, shows a cone-shaped monadonock, as illustrated in Pl. XLII, Fig. 2 and Pl. XLIII, Fig. 1, owing to its greater power of resistance against erosion than other places on which no dyke occurs. On the hill, about 300 m in elevation, it occurs as fine parallel dykes, 0.4 m–20 m in width, as shown in Pl. XLIII, Fig. 2. As many as 23 separate dykes can be observed on the above hill. Dykes occurring on Maru-yama do not, however, run so parallel with one another as the former, some of them being given in Pl. XLIII, Fig. 3.

As above stated, the rock occurs almost entirely as dykes in various places in the locality. It may be expected, therefore, that knowledge of the distribution will be extended by means of further geological study which the writer intends to carry out hereafter.

II. PETROGRAPHY

1. Macroscopical Character

In the specimen at hand, the rock is seen to be of compact and even texture. Although the fresh rock occasionally found in some outcrop is gray in colour with a bluish tone, it is usually a light yellowish brown. It is often stained by a reddish substance which fills its cavities and cracks, giving the rock a reddish tone. In appearance it is similar to a rhyolite, but examination under a hand-lens reveals that the phenocrysts consist mainly of fresh crystals of feldspar, 1–3 mm in length, while quartz is absent. In most of the rocks the dark mineral is hardly found.

2. Microscopical Character

Under the microscope, it is at once apparent that the rock, showing a porphyritic texture, seems to be of high crystallinity. As shown in Pl. XLIV, Fig. 5, the phenocryst is composed almost entirely of a clear, transparent anorthoclase, to which is often added a small amount of aegirite, which has usually altered to a reddish substance such as hematite.

Anorthoclase, which is the dominant phenocryst, is euhedral or subhedral, and usually shows a rectangular and wedge-shaped cross-section, as illustrated in Pl. XLIV, Fig. 5. It is usually a tabular crystal parallel to (010): some are short rectangular prisms elongated along the a-axis. The crystallographic faces observed are b(010), c(001), m(110), n(021) and y($\bar{2}01$). Owing to the remarkable development of many cracks in the mineral, cleavage is not generally so distinct, but those parallel to (010) and (001) can be observed. Carlsbad twinning, as seen in Pl. XLIV, Fig. 5, is common, while the albite is very rare. The fine microscopic lamellar twinning according to the combination of the albite and microcline laws rarely occurs. The optical properties measured by a universal stage are as follows:

$$\begin{aligned} \text{optical plane} \wedge (010) &= 88^\circ - 89^\circ \\ a \wedge X' \text{ on } (010) &= 8^\circ - 11^\circ \\ a \wedge X' \text{ on } (001) &= 4^\circ - 6^\circ \\ (-)\ 2V &= 34^\circ - 45^\circ \end{aligned}$$

The refractive indices determined by the immersion method are given below.

$$\alpha' = 1.523$$
$$\gamma' = 1.529$$

From the above optical properties, ranging in some extent, it may be considered that the chemical composition of the mineral, i.e., the ratio of orthoclase to albite, is not identical in all crystals.

Aegirite, which occurs in a small amount, is usually euhedral and shows a prismatic crystal, 0.5 mm in maximum length. It is rare in such a fresh crystal as shown in Pl. XLIV, Fig. 6 and is generally altered to a reddish substance which seems to be hematite. Cleavage parallel to (110) is dominant. It is strongly pleochroic with X=light grass green, Y=grass green, Z=bluish green. Absorption is strong, $Z > Y > X$. The optic axial angle measured by a universal stage is given below.

$$(-)\ 2V = 61^\circ$$

Quartz, which occurs very rarely, generally shows a corroded form.

Magnetite, which is contained as an accessory mineral, is present in a very small amount, forming small crystals of irregular shape.

The groundmass is usually colourless except for the reddish brown parts stained by iron oxide, and often shows a flow texture recognized with difficulty, as illustrated in Pl. XLIV, Fig. 5. It is appears to be composed essentially of a small amount of granular quartz, which encloses only glass grains in slightly less in amount, as shown in Pl. XLV, Fig. 1, and a great amount of a cryptocrystalline basis consisting of alkali feldspar and quartz. It appears also to show a felsitic texture caused by devitrification. Examining it with an objective of high power, however, it may be classified, by its texture, into the following four types:

α. When a slide is examined under crossed nicols, it will be found that the groundmass is composed of small patches of low birefringent minerals which are extinguished simultaneously over some little area, and a little grains of clear, transparent quartz scattered in the small patch, as illustrated in Pl. LXV, Fig. 1. The patches usually contain a large amount of acicular crystallite, which has a low refringence and a weak birefringence. It may be considered that the former is quartz, while the latter is alkali feldspar rich in potassium. From the above evidence, it is thought that quartz and alkali feldspar, which have had to crystallize out as a eutectic mixture, have shown an indistinct texture nearly similar to the micrographic one.

β. In some dykes, alkali feldspar and quartz constituting small patches in the groundmass show a more distinct graphic intergrowth than the first type, as seen in Pl. XLV, Fig. 2.

γ. Alkali feldspar contained in the patches is often arranged in radial form. In such a rock, the patches show a comparatively distinct spherulitic texture, shown in Pl. XLV, Fig. 3.

δ. In some dykes, the groundmass is frequently composed of a glassy basis and a small amount of quartz crystals sparsely scattered in the former, as illustrated in Pl. XLV, Fig. 4.

Among the four types of texture, the first type is observed in most of the dykes which occur in the region, while the others are rare, developing only in several dykes.

The above stated four types may be classified by their general texture. In the groundmasses showing four different types of texture, the coarse crystalline bands shown in Pl. XLV, Figs. 5 and 6 are often observed. The band, being holocrystalline, is composed essentially of alkali feldspar, probably orthoclase, and quartz, with subordinate aegirite. The two minerals of the former mutually interpenetrate, forming a texture like the micrographic one, as illustrated in Pl. XLV, Fig. 5. The latter, showing generally a small prismatic crystal, is scattered in the graphic intergrowth of the two minerals of the former, as seen in Pl. XLV, Fig. 6. It is easily distinguished from other proxenes by the small extinction angle, the negative sign and negative elongation, and its characteristic absorption colour and characteristic pleochroism.

3. Chemical Character

The chemical composition of the rock, carefully analyzed by the writer, is given in Table X together with the norm.

TABLE X.

Wt. %		Norm		Ratio
SiO_2	73.59	Q	32.22	$\frac{\text{Sal}}{\text{Fem}} = 12.11$
TiO_2	0.22	Or	31.69	
Al_2O_3	11.22	Ab	27.77	$\frac{Q}{F} = 0.54$
Fe_2O_3	4.31	Ac	3.23	
FeO	0.34	Hy	0.20	$\frac{K_2O' + Na_2O'}{CaO'} = \infty$
MnO	0.02	Mt	0.46	
MgO	0.07	Hm	2.88	
CaO	0.15	Il	0.46	$\frac{K_2O'}{Na_2O'} = 1.08$
Na_2O	3.74	Ap	0.34	
K_2O	5.33			I'', (3) 4, 1, 3
P_2O_5	0.09			Liparose
$H_2O +$	0.90			
$H_2O -$	0.19			
Total	100.17			

In order to compare the rock with comendites from other localities, Table XI is given.

TABLE XI.

	I	II	III	1V	V
SiO_2	73.59	72.21	73.38	74.76	74.44
TiO_2	0.22	0.44	0.28	tr.	0.19
Al_2O_3	11.22	11.20	11.88	11.60	11.27
Fe_2O_3	4.31	2.25	2.32	3.50	2.78
FeO	0.34	2.66	1.91	0.19	0.94
MnO	0.02	0.10	0.10	—	0.08
MgO	0.07	0.08	tr.	0.18	0.35

TABLE XI.—*Continued*

	I	II	III	IV	V
CaO	0.15	0.27	0.54	0.07	0.21
Na_2O	3.74	4.29	4.08	4.35	4.18
K_2O	5.33	4.81	5.05	4.92	4.95
P_2O_5	0.09	0.10	0.08	tr.	0.02
H_2O +	0.90	1.45	0.30	0.64	0.59
H_2O −	0.19	—	0.14	—	—
Total	100.17	99.86	100.06	100.21	100.00

I. Comendite, Maru-yama near Tyurui, Tokati, Hokkaido. T. NEMOTO, analyst.
II. Comendite, Iibi, Dôgo, Japan. K. YOKOYAMA, analyst(1).
III. Comendite, Kaisindo, Meisen, Korea. M. RAOULT, analyst(2).
IV. Comendite, Comende, San Pietro Island, Sardinia. M. DITTRICH, analyst(3).
V. Comendite, average of 6 analyses(4).

As shown in the above table, the chemical composition of the rock is quite identical with those of rocks from Oki Island, Korea and Sardinia, and with the average value of comendite.

In order to have the chemical relationship of these rocks made more obvious, their chemical compositions are recalculated to 100%, eliminating with water which is not so important in the main composition of magma. Then, from the recalculated value may be obtained the molecular numbers of the important components, as well as the values of Na_2O+K_2O, and $Al_2O_3-(Na_2O+K_2O)$, which may be conveniently multiplied by 1000, as given in Table XII.

(1) S. KÔZU: Petrological Notes on the Igneous Rocks of the Oki Islands. Sci. Rep. Tohoku Imp. Univ., Ser. 2, Vol. I, 1913, pp. 37–38.

(2) A. LACROIX: Les rhyolite et les trachytes hyperalcalins quartzifères, à propos de ceux de la Corée. Comp. Rend. Ac. Sci., t. 185, 1927, pp. 1410–1415.

(3) H. ROSENBUSCH: Elemente der Gesteinslehre, 1910, S. 332.

(4) R. A. DALY: Igneous Rocks and Their Origin, 1914, p. 20.

TABLE XII.

	I	II	III	IV	V
SiO_2	1238	1223	1228	1251	1248
Al_2O_3	111	112	117	114	111
Na_2O	61	70	66	71	68
K_2O	57	52	54	53	53
$Na_2O + K_2O$	118	122	120	124	121
$Al_2O_3 - (Na_2O + K_2O)$	−7	−10	−3	−10	−10
CaO	3	5	10	1	4
Fe_2O_3	27	14	15	22	18
FeO	5	38	27	3	13

I. Maru-yama, Tokati. II. Iibi, Dôgo.
II. Kaisindo, Korea. IV. Comende, Sardinia.
V. Average of 6 analyses.

To know both the relations by which it may be judged whether the rock under consideration is rich in either Na_2O or K_2O and whether the amount of sodic coloured mineral contained in the rock is much or little, the values of Na_2O+K_2O, Na_2O/K_2O, Na_2O and Fe_2O_3+FeO are quoted in Table XIII.

TABLE XIII.

	I	II	III	IV	V
$Na_2O + K_2O$	118.	122.	120.	124.	121.
$\frac{Na_2O}{K_2O}$	1.07	1.35	1.22	1.34	1.28
Na_2O	61.	70.	66.	71.	68.
$Fe_2O_3 + FeO$	32.	52.	42.	25.	31.

I. Maru-yama, Tokati. II. Iibi, Dôgo.
III. Kaisindo, Korea. IV. Comende, Sardinia.
V. Average of 6 analyses.

Further, these values are plotted on the diagrams, Fig. 5 and Fig. 6, which are a new scheme proposed by the writer as in the case of aegirine-augite hyalo-rhyolite, ôkawaite.

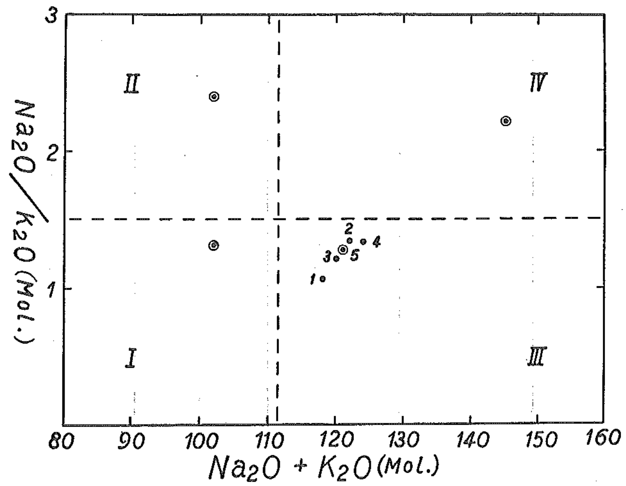

Fig. 5.

1. Maru-yama, Tokati.
2. Iibi, Dôgo.
3. Kaisindo, Korea.
4. Comende, Sardinia.
5. Average of 6 analyses.

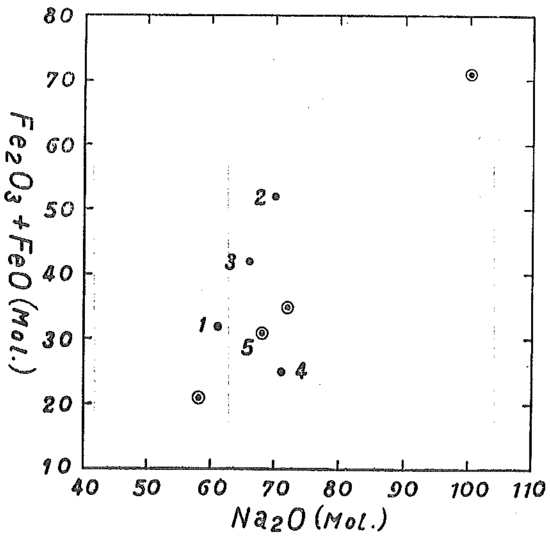

Fig. 6.

1. Maru-yama, Tokati.
2. Iibi, Dôgo.
3. Kaisindo, Korea.
4. Comende, Sardinia.
5. Average of 6 analyses.

From Fig. 5, it is clear that the rock which occupies Field III has a value nearly identical with the averaged comendite as well as the others, that is to say, that the rock is rich not only in alkali, but also in K_2O. Moreover, it is obvious from Fig. 6, that the rock is comparatively as rich in sodic coloured mineral as the other comendites and the averaged one. In other words, the rock under consideration has the chemical characteristics of comendite just as the other rocks.

4. Summary

The mineralogical and chemical characteristics of the rock which were cited in the above lines are enumerated below:

1. The phenocryst is composed essentially of anorthoclase and aegirite, which are the characteristic minerals of alkaline rhyolite, and lacks entirely plagioclase and some coloured minerals which are low in alkali and rich in CaO and MgO.
2. In the value of molecular ratio, alkali is greater than alumina.
3. In weight percentage, the value of K_2O is higher than that of Na_2O, although the value of Na_2O/K_2O is 1.07 by molecule.
4. In the relation of Na_2O/K_2O to Na_2O+K_2O, it shows the nearest analogy with the averaged comendite, as well as with the others.
5. In the relation of Fe_2O_3+FeO to Na_2O, it is also approximately similar to the averaged comendite and the others.

From the evidence cited, it may be concluded that the rock under consideration has the mineralogical and chemical characteristics of comendite, though it lacks clearly distinguishable alkali amphibole.

ACKNOWLEDGMENTS

The painstaking criticism of the manuscript and helpful discussions of the problem by Prof. Jun SUZUKI and Prof. Zyunpéi HARADA of Hokkaido Imperial University, and by Prof. Shukusuké KÔZU of Tôhoku Imperial University, are gratefully acknowledged. The writer is also indebted to the Geological Committee of Hokkaido for a grant which afforded him the opportunity of accomplishing this investigation.

Plate XLII (I)

PLATE XLII (I)

Fig. 1. Outcrop in the upper course of the Ôkawa. The upper part, flow of aegirine-augite hyalo-rhyolite, ôkawaite; the lower part, lower Oikamanae bed.

Fig. 2. Maru-yama viewed from south, showing a cone-shaped monadonock.

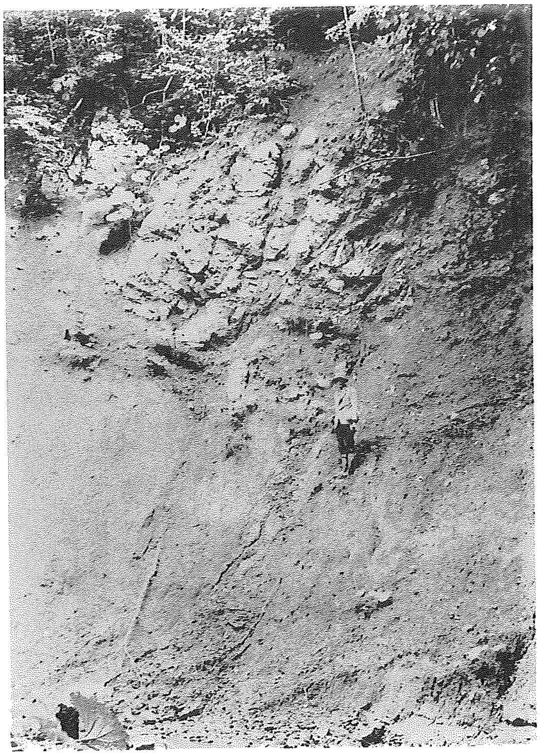

Fig. 1.

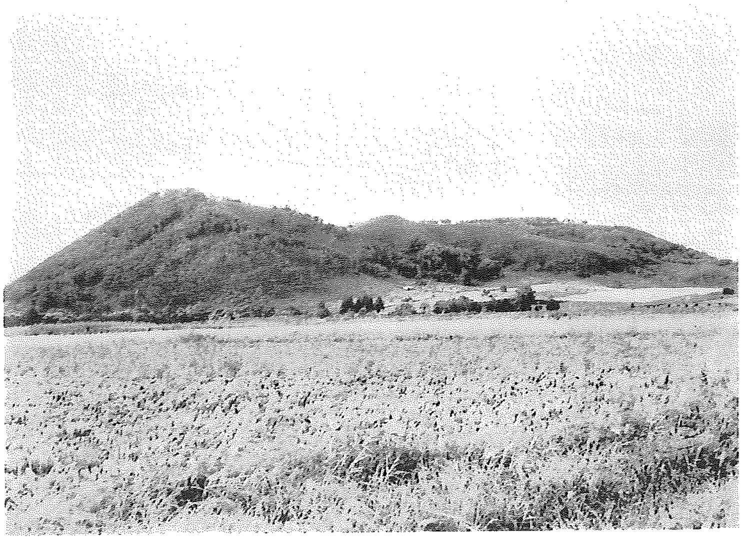

Fig. 2.

T. Nemoto: Alkaline Rhyolites from Tokati.

Plate XLIII (II)

PLATE XLIII (II)

Fig. 1. Maru-yama (left) viewed from east, showing a cone-shaped monadonock.

Fig. 2. Dykes of comendite, occurring on the hill, about 300 m in elevation.

Fig. 3. Dykes of comendite, occurring on Maru-yama.

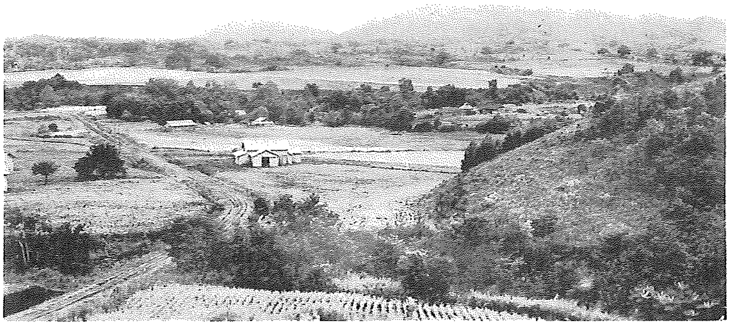

Fig. 1.

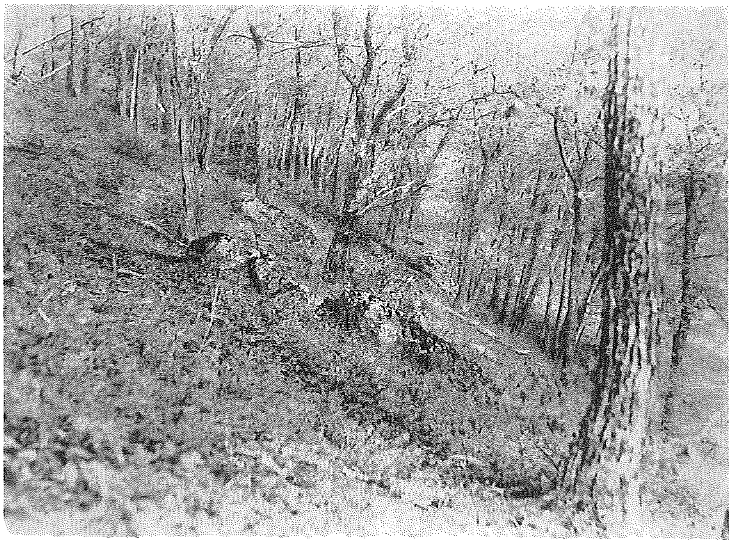

Fig. 2.

Fig. 3.

T. Nemoto: Alkaline Rhyolites from Tokati.

Plate XLIV (III)

PLATE XLIV (III)

Fig. 1. The general texture of aegirine-augite hyalo-rhyolite, ôkawaite, from the Ôkawa. Ordinary light. ×26. An, Anorthoclase; Ae, Aegirine-augite; L, granular mineral after leucite.

Fig. 2. Anorthoclase (An) in aegirine-augite hyalo-rhyolite, ôkawaite. Ordinary light. ×17.

Fig. 3. Aegirine-augite (Ae) in aegirine-augite hyalo-rhyolite, ôkawaite. Ordinary light. ×32.

Fig. 4. Granular mineral after leucite (L) in aegirine-augite hyalo-rhyolite, ôkawaite. Ordinary light. ×51.

Fig. 5. The general texture of comendite from Maru-yama, showing the phenocrysts of anorthoclase (An), and flow texture of the groundmass. Ordinary light. ×19. The lower phenocryst of anorthoclase shows Carlsbad twinning.

Fig. 6. Aegirite (A) in comendite. Ordinary light. ×82.

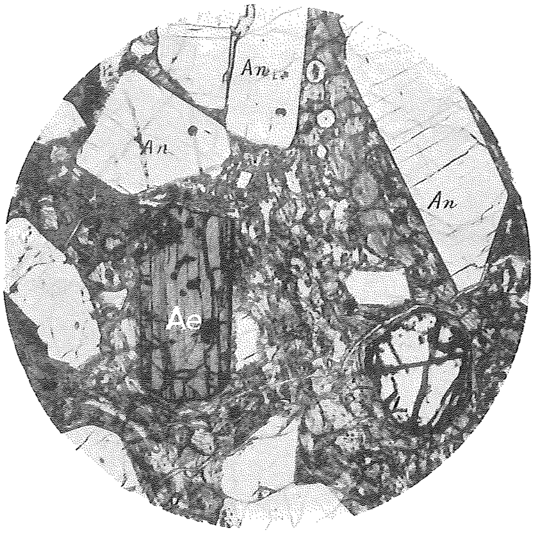

Fig. 1.

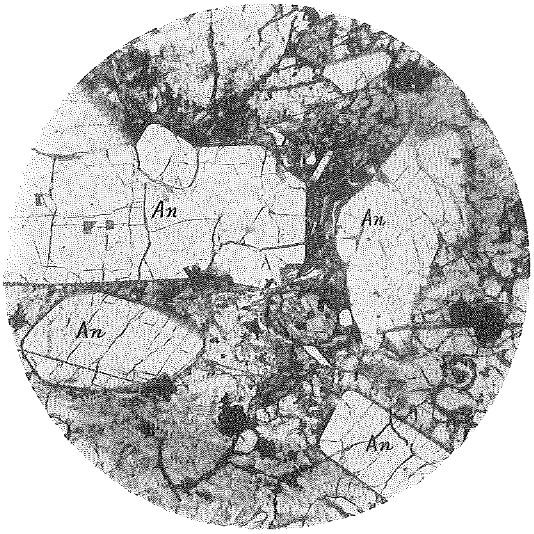

Fig. 2.

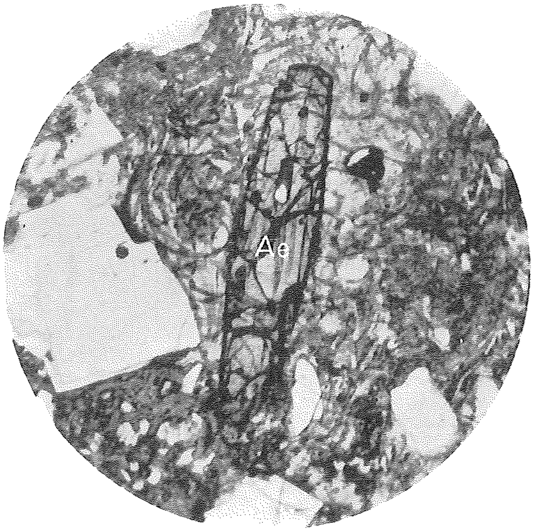

Fig. 3.

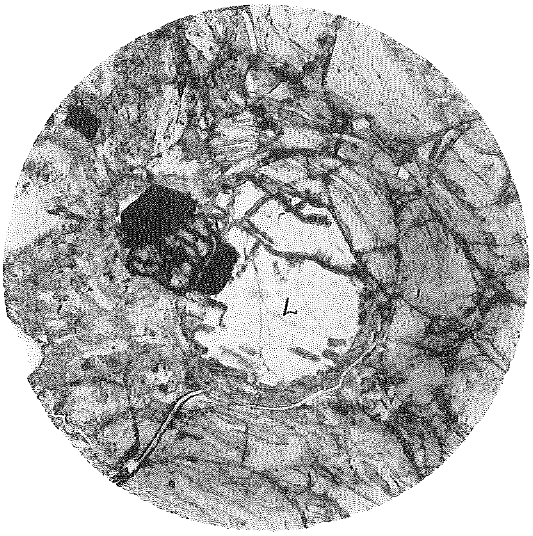

Fig. 4.

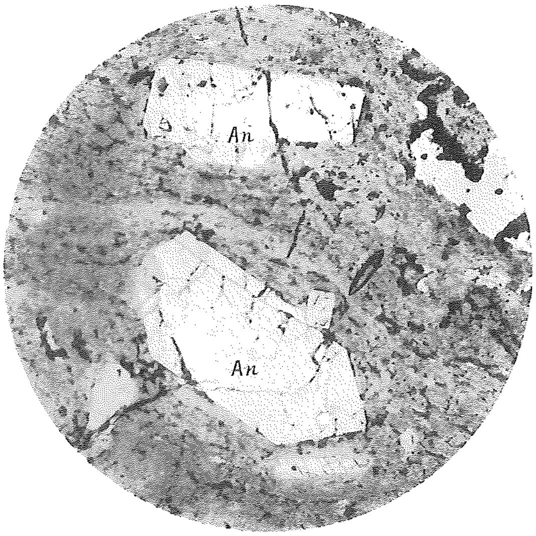

Fig. 5.

Fig. 6.

T. Nemoto: Alkaline Rhyolites from Tokati.

Plate XLV (IV)

PLATE XXLV (IV)

Fig. 1. α–type groundmass of comendite. Nicols crossed. $\times 69$. Q, small crystal of quartz.

Fig. 2. β–type groundmass of comendite. Nicols crossed. $\times 87$.

Fig. 3. γ–type groundmass of comendite. Nicols crossed. $\times 66$.

Fig. 4. δ–type groundmass of comendite. Nicols crossed. $\times 56$.

Fig. 5. Coarse crystalline band in the groundmass of comendite, showing a texture like the micrographic one.
Nicols crossed. $\times 84$.

Fig. 6. Coarse crystalline band in the groundmass of comendite.
Ordinary light. $\times 108$.
A, Aegirite.

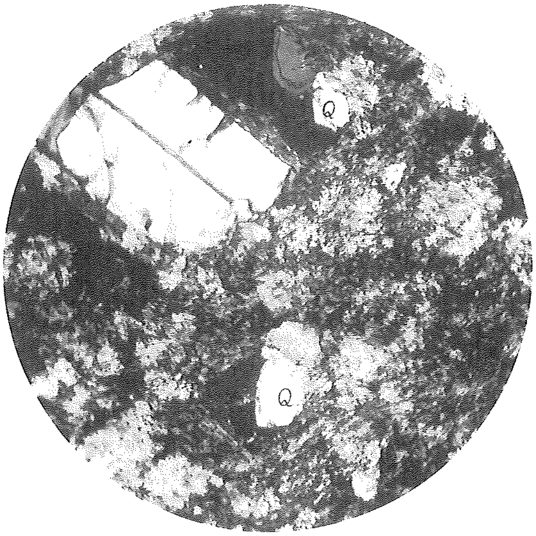

Fig. 1.

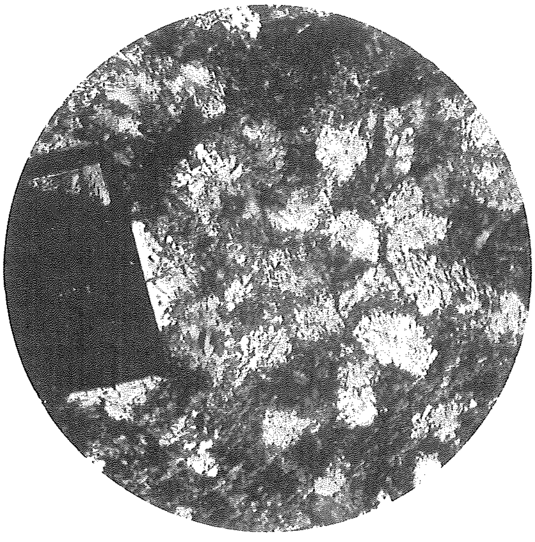

Fig. 2.

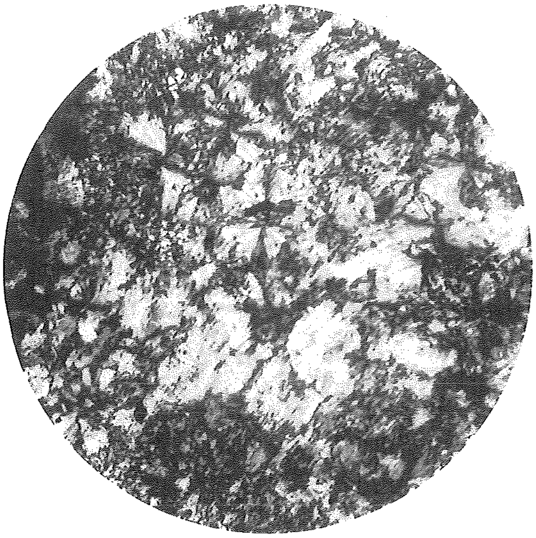

Fig. 3.

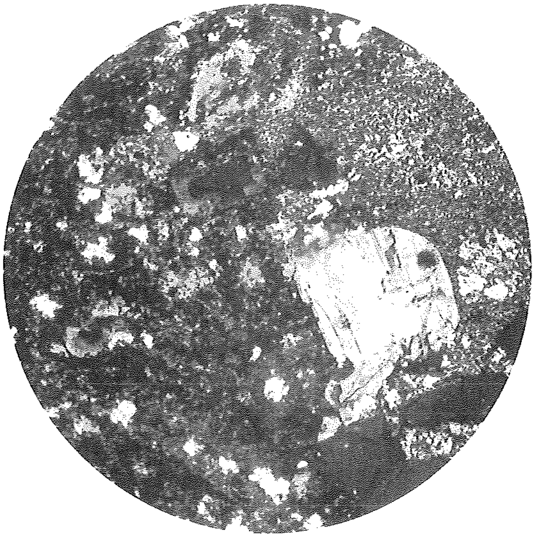

Fig. 4.

Fig. 5.

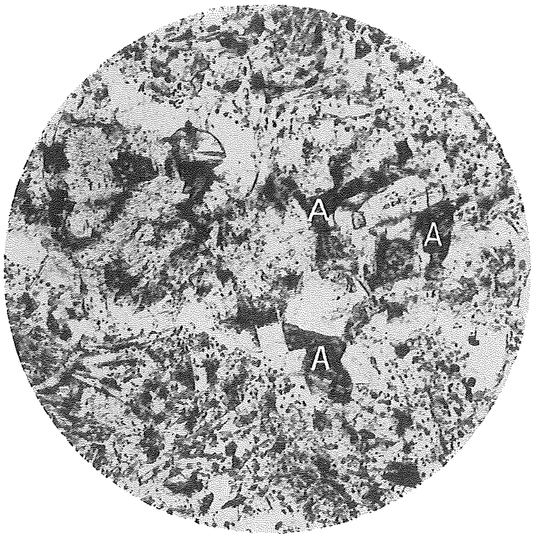

Fig. 6.

T. Nemoto: Alkaline Rhyolites from Tokati.