ON THE OCCURRENCE OF AEGIRINE-AUGITE IN NATROLITE VEINS IN THE DOLERITE FROM NEMURO, HOKKAIDÔ

By

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With 1 Plate and 3 Text-figures

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INTRODUCTION

In the Nemuro Peninsula, the eastern extreme of Hokkaidô, there is an extensive area of the Senonian Formation, which is generally monoclinal with a NEE trend and a dip $15 \sim 20°$ to SSE. The formation is locally cut by innumerable sills and lavas of doleritic rocks which vary in thickness from ten to twenty meters. Very pretty joints in platy or radial form are observed in the rocks at certain localities. The doleritic rocks have attracted the petrologist's attention on account of their containing analcime phenocrysts and being penetrated by numerous zeolite veinlets. According to Y. SASA,[1] similar igneous rocks are extensively developed in Sikotan Island which is situated at the eastern extremity of the frontal zone of the South Kurile Islands.

The present writer made a journey with Y. SASA in the peninsula in the summer of 1932 and collected various samples of the doleritic rocks from localities in Nemuro-town, Bentenzima (Islet) and the Hanazaki Cape where crop out excellent exposures of the rock. During the examination of the specimens in the laboratory, the writer

(1) Y. SASA: Proc. Fifth Pacific Sci. Congr., Canada (1933), p. 2479.

found some noticeable samples in which the original constituents alter into fine secondary minerals by the action of percolating soda-rich solutions. The following notes are with special reference to the aegirinization of common augite with which are associated zeolitization of feldspar and serpentization of olivine in the doleritic rocks. Before treating the subject prefer a short description of the petrology of the original rocks may be necessary for the sake of convenience.

PROPERTIES OF THE DOLERITE

The doleritic rocks in the district, are grayish to dark grayish colour ranging from coarse grained to aphanitic. From the mineral composition, they are roughly classified into three main types: analcime olivine dolerite, analcime hornblende dolerite and lencocratic dolerite. Of these rocks, analcime olivine dolerite with porphyritic texture is the most common in the district. Its detailed study has already been described by F. HOMMA[(1)] in 1928.

Under the microscope, the typical porphyritic rock is composed of phenocrysts of feldspar, pyroxene, and analcime and ophitic or intersertal groundmass which consists of a mixture of minute crystals of feldspar, pyroxene, specks of magnetite and dark glassy matter. (Fig. 1 and Pl. XVII (I), Fig. 1.)

The feldspar is the most important constituent of the rock. The phenocrysts of that mineral generally show multiple twinning after the albite and occasionally the pericline laws. The crystal form is exact, $0.5 \sim 1.0$ mm. in length, and the zonal structure is predominant in most crystals. By examination under the universal stage, it shows $(+)2V = 84 \sim 85°$ indicating that it is a labradorite-bytownite with an anorthite percentage composition An_{65}.

The pyroxene is an essential component next to the feldspar. It is usually idiomorphic, $1 \sim 2$ mm. in diameter. Fine lamellar twinning on (100) is frequently developed. The optic axial plane is parallel to (010) and Y coincides to b-axis. The optic axial angle is $(+)2V = 50 \sim 57°$ and the maximum extinction angle on (010) is $Z : c = 42 \sim 48°$. The refractive index of the cleavage flakes on (110)

(1) F. HOMMA: Commenoration Volume Dedicated to Prof. T. OGAWA, on the Occasion of his Sixtieth Birthday. Kyoto. 1930, pp. 38–45.

by oil immersion, is as follows: $n_1(\mathrm{D}) = 1.695$ and $n_2(\mathrm{D}) = 1.713$. Pleochroism is not very marked, with X and Y = colourless to pale green, Z = light yellowish green and absorption $Z > Y = X$. These properties indicate a mineral closely approaching common augite in composition.

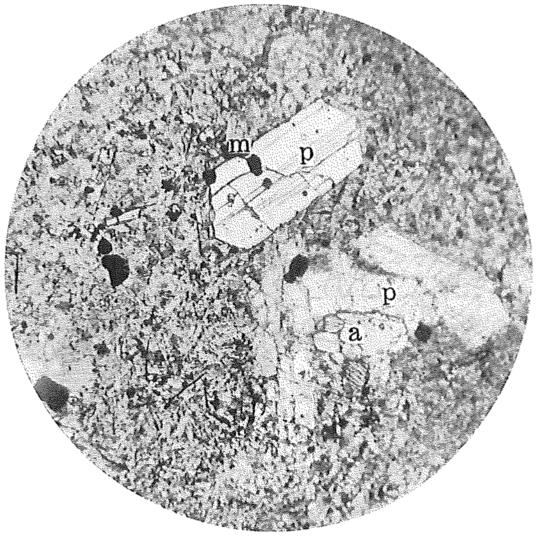

Fig. 1. Analcime dolerite f.om Bentenzima near Nemuro. ×22, p: plagioclase (labradorite-bytownite) a: analcime, m: magnetite.

Olivine is one of the predominant constituents of the rock though it is almost absent in the analcime hornblende dolerite. It appears as perfectly fresh colourless crystal, 0.3 ~ 0.8 mm. in longer diameter, but is afterwards almost altered to colourless serpentine or green chloritic matter. Frequently the mineral is enclosed in the phenocryst of common augite. Analcime is found in a slight extent to the rock occurring as small rounded grains with a size of 0.2 ~ 0.3 mm. in diameter. Some of the grains occur as an inclosure in the feldspar phenocrysts in the rock. The grains are quite colourless and almost isotropic under the cross nicols. The chemical analysis of the mineral in the rock from Bentenzima, an islet near Nemuro, was made by H. YOSIZAWA, giving the following result.(1)

(1) H. YOSIZAWA: Tikyu (The Globe) **14** (1930) p. 411.

TABLE I.

	wt. %	mol. %
SiO_2	55.64	50.4
Al_2O_3	21.43	11.5
CaO	1 06	1.0
MgO	0.21	0.3
Na_2O	12.14	10.7
K_2O	0.21	0.1
H_2O (above 70 C)	8.60	26.0
Total	99.29	100.0

(Sp. gr. 2.257)
Analcime in the dolerite from Bentenzima, Nemuro
(Analyst, H. Yosizawa)

Calculating from the molecular value of the mineral it corresponds on the whole to the theoretical value of analcime.

Microlite of feldspar in the groundmass is $0.1 \sim 0.3$ mm. in long diameter and is more basic than the phenocryst of the same mineral.

TABLE II.

	wt. %	mol. %
SiO_2	51.05	56.3
TiO_2	0.59	0.5
Al_2O_3	16.43	10.7
Fe_2O_3	2.81	1.2
FeO	5.18	4.8
MnO	0.17	0.1
MgO	6.18	10.2
CaO	7.67	9.1
Na_2O	3.45	3.7
K_2O	3.38	2.4
P_2O_5	0.42	1.0
H_2O (+)	2.19	—
H_2O (−)	0.79	—
Total	100.31	100.0

Analcime olivine dolerite from Bentenzima near Nemuro
Hokkaidô (Analyst, U. Usizima)

A little magnetite, sphane, ilmenite and apatite may also be present as original constituents of the rock. The glass base of the rock is dark brownish in colour and fills up the interspaces of all constituent minerals.

The chemical analysis of the typical analcime olivine dolerite from Bentenzima near the town of Nemuro, as reported in the HOMMA's paper,(1) is quoted here in Table II.

OCCURRENCE OF AEGIRINE-AUGITE IN NATROLITE VEINS

The doleritic rocks in the district are partly penetrated by veinlets filled with zeolite and a minute amount of quartz and calcite, which were probably due to the percolation of solutions containing soda expelled from the consolidating doleritic magma. The zeolite shows crowds of fibrous crystals, $1 \sim 4$ cm. in length. It is almost colourless and shows an extremely low index of refraction and birefringence. According to H. YOSIZAWA(2) the chemical composition of the zeolite is as follows:

TABLE III.

	wt. %	mol. %
SiO_2	44.27	38.4
Al_2O_3	26.66	13.6
CaO	4.69	4.1
MgO	0.35	0.5
Na_2O	13.06	11.3
K_2O	0.14	0.1
H_2O (above 70 °C)	11.07	32.0
Total	100.24	100.0

(Sp. gr. 2.225)
Zeolite forming the vein in the dolerite from Nemuro
(Analyst, Y. Yosizawa)

(1) F. HOMMA: Loc. cit. p. 40.
In the original paper the total is calculated as 100.26.

(2) H. YOSIZAWA: Op. cit. p. 413.

The analysis of zeolite is very close to that of natrolite but it has a smaller content especially of lime, indicating that it contains some amount of scolecite molecule as an isomorphous mixture.

Calcite and quartz in the veinlets occur as minute grains or patches filling up the crowds of natrolite needles. No exact crystal forms are observed in these minerals.

It is most remarkable that the constituent minerals in the original dolerite, which were effected by the action of percolating soda-rich solution, usually transform to secondary products: common augite alters into aegirine-augite, plagioclase into natrolite and olivine into serpentine or chloritic matters. The zeolite veinlets occasionally enclose entirely altered fragments of the above mentioned minerals, which obviously represent particles picked up by the solution during its penetration the fissures in the dolerite.

It is interesting that the common augite is sharply aegirinized only in the portion where the crystal is directly in contact with the natrolite veinlet though the most of the plagioclase and olivine crystals alter into the secondary products not only in the veinlets themselves but also in the neighbouring portion of them (Pl. XVIII (I), Figs. 2 and 3.) In the latter case, there is some exceptions where the center of the larger phenocrysts of these minerals may remain practically unaltered.

Aegirine augite which was newly formed by the action of soda-rich solution on common augite, shows fine crystal form and usually very fresh appearance containing no inclusions. The optical plane of the mineral is parallel to (010) and $Y = b$. Some crystals show zonal and hourglass structures under the cross nicols.

Comparing with common augite, the aegirinized part shows quite different optical properties, on colours, extinction angle, optic axial angle, index of refraction and birefringence, etc. The optical data of these minerals are set down in Table IV.

When the aegirine-augite intergrows with the unaltered common augite in an individual, they have a common optical plane in mutual position, namely (010) // (010). The relation between these minerals is shown in the following diagrammatic and stereogrammatic figures (Figs. 2 and 3).

From the mode of occurrence, the origin of aegirine-augite in the vein is clearly due to the metasomatic action between the common augite and soda-rich solutions which were expelled as residual liquids at the crystallization of the doleritic rock. In this case it

TABLE IV.

Common Augite	Aegirine-augite
Pleochroism	Pleochroism
X = colourless to pale green	X = pale grass green
Y = pale green	Y = light green
Z = light yellowish green	Z = light yellowish green
Absorption	Absorption
$Z > Y = X$	$Z < Y < X$
Index of refraction	Index of refraction
$n_1(D) = 1.695$	$n_1(D) = 1.709$
$n_2(D) = 1.713$	$n_2(D) = 1.728$
Extinction angle	Extinction angle
$Z : c = 45\sim48°$	$Z : c = 55\sim57°$
Optic axial angle	Optic axial angle
$(+)2V = 50\sim57°$	$(+)2V = 60\sim74°$
Dispersion $\rho > v$	Dispersion $\rho > v$

may be considered probable that the soda was concentrated in the form of sodium carbonate, and the silica in the form of silica gel in the ascending solution. The secondary development of aegirine or aegirine-augite along the periphery zone of the original pyroxene crystals, by the metasomatic action of percolating soda-rich solution, is not less common.(1) Familiar examples in Japan on this subject have been reported by many authors for the doleritic rocks from Kasiwagi(2) and Onisi(3) along the Kanna River in Gunma Pref., Takakusa Yama(4) in Sizuoka Pref., and Esutoru(5) in South Sakhalin, etc. In the rocks from these localities, the newly formed aegirine or aegirine-augite is usually accompanied by albite crystals or veinlets. It is, however, worthy of note that in the dolerite from Nemuro, now in question, aegirine-augite occurs only in zeolite veins and associated no albite crystals with itself. As already stated, aegirine-augite crystals in the veinlets usually show fine form and contain no

(1) V. M. GOLDSCHMIDT: Neues Jahrbuch f. Min., **39** (1914) p. 193 and Econ. Geol. **17** (1922) p. 109.

(2) J. SUZUKI: Jour. Jap. Ass. Petr. Min. and Econ. Geol. **7** (1932) p. 205.

(3) Y. HORIKOSI: Jour. Geol. Soc. Japan. **41** (1934) p. 731.

(4) T. TOMITA: Jour. Geol. Soc. Japan. **44** (1937) p. 974.

(5) M. ISIBASI: Jour. Jap. Ass. Petr. Min. and Econ. Geol. **18** (1937) p. 293.

inclusions in them, on the other hand the natrolite needles fill up the interspaces among the crystals of the former mineral. This fact

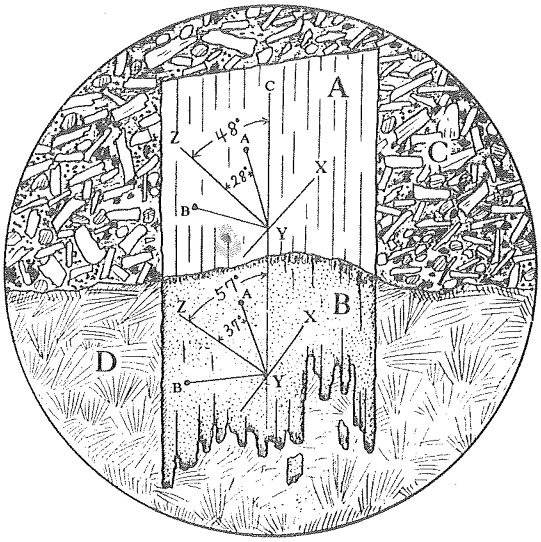

Fig. 2. Diagrammatic sketch of the crystal, parallel to (010), showing an intergrowth of common augite (A) and aegirine-augite (B). In the figure (C) means the groundmass of dolerite and (D) the natrolite vein.

indicates that the crystallization of aegirine-augite took place at an early stage of the ascending soda-rich solution, and natrolite occurred as the final product in the vein.

To state it more precisely, the following explanation is probable for the formation of the minerals in the veinlets. At an early stage of the vein, there occurred firstly a mixture of aegirine-augite and albite, as a result of the action of soda-rich solution and the original constituent minerals in the dolerite. It is generally believed that high temperatures are not essential to the formation of zeolite.(6) Then by the further action of the solution at descending temperature, the albite crystals were completely natrolitized while the embedded crystals of aegirine-augite retained their form almost unchanged. It

(6) P. ESKOLA in connection with an experimental illustration of the spilite reaction, has given a valuable conclusion on the origination of albite and zeolite. (Extrait des Comptes Rendus de la Société Géologique de Finlande No. 9, 1935, pp. 1–8).

is possible to consider the origination of some amounts of calcite and quartz in the vein, in the course of the consolidation of the solution.

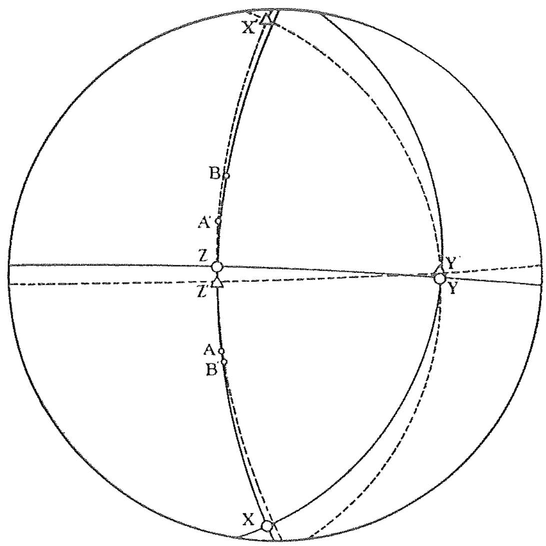

Fig. 3. Stereogram showing the relation between common augite and aegirine-augite. Full line and circle for common augite, and dotted line and triangle for aegirine-augite.

In short, the reaction between the original minerals and soda-rich solution may be expressed by the following equations:

(1) $4(CaO.(Fe.Mg)O.2SiO_2)+2(CaO.Al_2O_3.2SiO_2)Na_2O.Al_2O_3.6SiO_2$
(Common augite) (Labradorite-bytownite)
$+3(Na_2O.CO_2)+8SiO_2+CO_2+O = Fe_2O_3.Na_2O.4SiO_2.2(CaO.MgO.2SiO_2)$
(Aegirine-augite)
$+3(Na_2O.Al_2O_3.6SiO_2)+4(CaO.CO_2)$
(Albite) (Calcite)

(2) $Na_2O.Al_2O_3.6SiO_2+2H_2O = Na_2O.Al_2O_3.3SiO_2.2H_2O+3SiO_2$
(Albite) (Natrolite) (Quartz)

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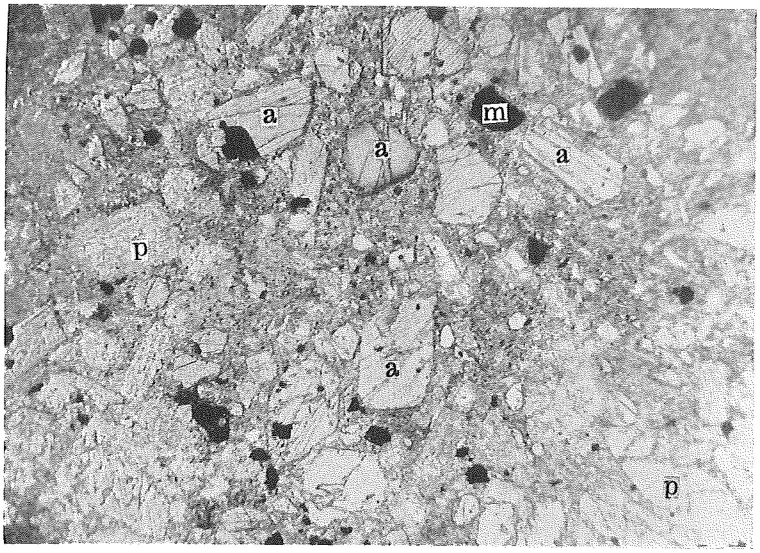
Plate XVII (I)

PLATE XVII (I)

Fig. 1. Dolerite from Bentenzima near Nemuro. $\times 22$. a: common augite, p: labradorite-bytownite, m: magnetite.

Figs. 2–3. Dolerite being penetrated by natrolite veinlet. $\times 40$. a: common augite, ae: aegirine-augite, n: natrolite, p: labradorite-bytownite.



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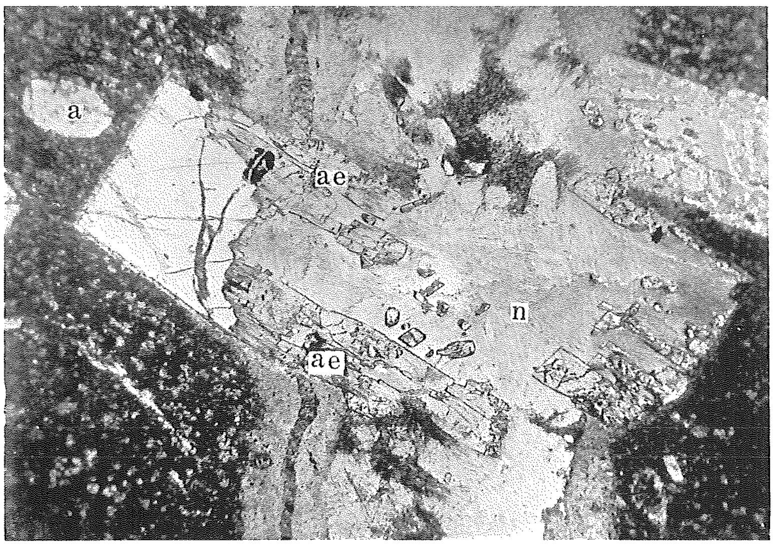

Fig. 2.

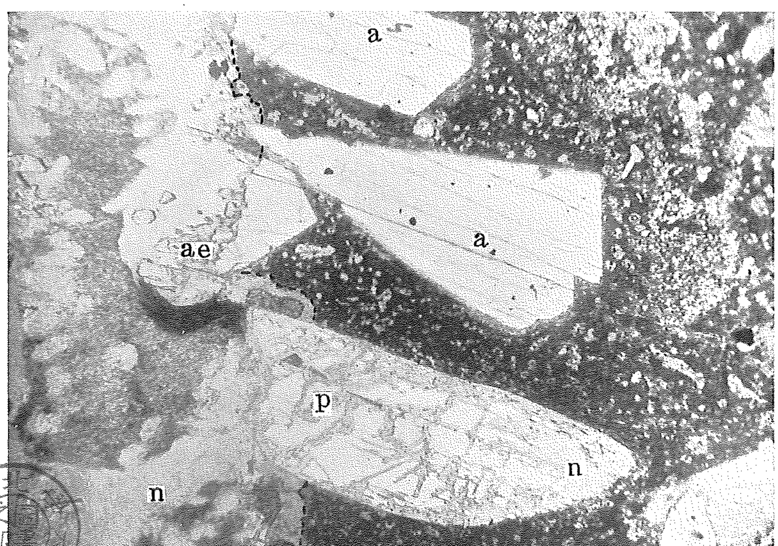

Fig. 3.

J. Suzuki: Occurrence of Aegirine-Augite in Natrolite Veins