

## A Pale Coloured Aegirine from the Kamisugai Mine, Ehime Prefecture, Japan

By

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### Introduction

During the geological and mineralogical survey of Shikoku by the second and third authors in 1975, they visited the dump of the regionally metamorphosed bedded iron-manganese ore deposits of the Kamisugai mine, Ohzu City, Ehime Prefecture, where a brown grey prismatic mineral was found as veinlets cutting hematite or braunite ores. The X-ray powder diffraction study and chemical analysis indicated the mineral to be an aegirine approximately consisting of  $Ac_{80}Di_{10}Jd_{10}$  in composition with very low MnO content as compared with aegirines hitherto reported in contact or regionally metamorphosed bedded iron-manganese or manganese ore deposits in Japan.

The present report describes the mineralogical properties of this unusually pale coloured aegirine and the result of consideration about the genesis, that is, it is the product under highly oxidizing condition impoverishing divalent manganese ion, together with the outlining of compositional variation of aegirines found in metamorphosed iron-manganese or manganese ore deposits, starting from the present aegirine to calcium-poorer johannsenite through aegirine and aegirine-augite with poorer contents of larger cations.

The authors are greatly indebted to Dr. Takamitsu YAMANAKA, Mineralogical Institute, University of Tokyo, for his microprobe analysis of the studied aegirine.

### Occurrence

The ore deposits of the Kamisugai mine are located about 4 km northwest of Ohzu station of Yosai line, Japan National Railway (Fig. 1). They were worked for manganese and iron during the World War II but now closed. They are all of bedded type and developed within quartz schist intercalated with green schist belonging to the Sambagawa metamorphic rocks. The ore-bearing horizon is traced over about 1000 meters along the strike with swollen parts forming orebodies, which are more than five in total number. The general strike is east-northeast and the dip angle is very low northwards. Since all the ore deposits had been entirely worked out, all the studied materials were collected from the dump.

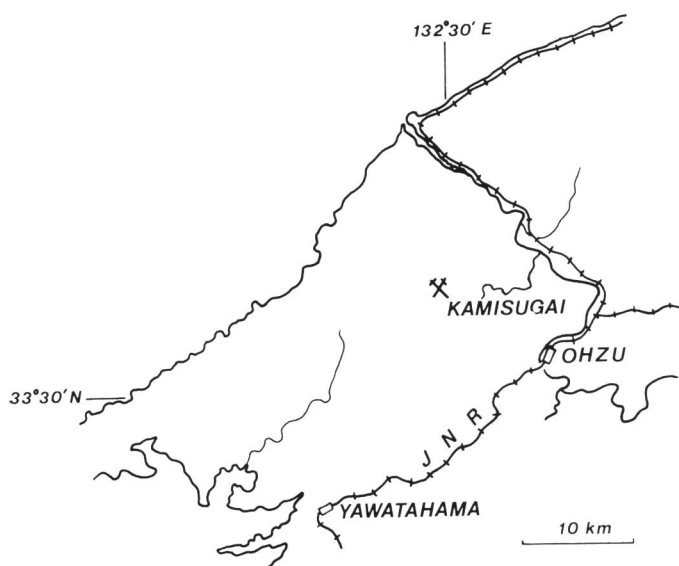


Fig. 1. Index map of the Kamisugai mine (crossed hammer mark).

The principal ore minerals of manganese and iron are braunite and hematite, respectively, with subordinate amounts of rhodonite, spessartine, piemontite and a jacobsonite-like mineral. The principal gangue mineral is quartz with a light pinkish muscovite.

Aegirine occurs as veinlets cutting hematite or braunite ore, and the material of the former occurrence is here studied. The aegirine veinlets cutting hematite ore have apparently sharp walls with minute disturbances due to small scale branches and very minute prismatic crystals of aegirine developed perpendicularly to the walls. The veinlets have a brown grey colour with local stains of manganese dioxide and reach 1 cm in maximum width. Apparently, they are fully stuffed by aegirine with minor quartz, forming patches therein. Generally in the middle of veinlets, the prisms of aegirine are well developed as compared with those in the marginal part where it forms a mosaic texture composed of shorter prisms or granular crystals. Fig. 2 is the representative aspect of the mineral association in the veinlets.

The veinlets developed in massive braunite ore have a similar appearance. But under the microscope the walls are not so smooth due to the development of inclusions of hypidiomorphic braunite grains of 0.0n mm order. Also they are richer in sub-round aggregates of quartz of 0.n mm order than the previous one.

Besides the present aegirine, YOSHIMURA (1969) reports the occurrence of a yellow pyroxene in rhodonite-quartz ore from the ore deposit. Under the microscope, it occurs as the aggregate of brownish yellow grains with a strong pleochroism. Therefore, the mode of occurrence is entirely different from that of the present aegirine,

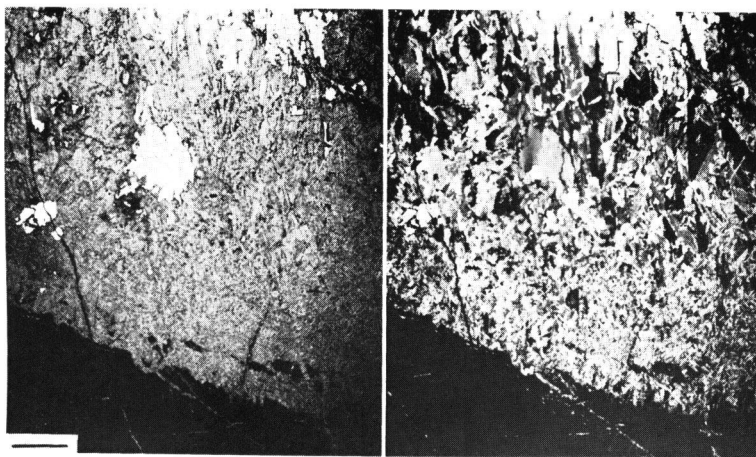


Fig. 2. Photomicrographs of thin section of aegirine (grey) and quartz (white) cutting hematite (black, occupying bottom part). Note that manganese dioxide (black, stringer-like) veinlets cut aegirine and quartz, and the extension in hematite is devoid of any vein stuff. One polar (left) and crossed polars (right). (Scale bar indicates 0.2 mm)

and this yellow pyroxene is considered to be a manganoan aegirine or aegirine-augite seeing from the apparent colour and optical properties. This aegirine was not found during the visit of this time.

### Physical Properties

The aegirine has a light brown grey colour with a vitreous luster and paler streak. Calculated density is  $3.52 \text{ g/cm}^3$ . In thin section, the mineral has very pale brown grey colour without pleochroism. The refractive indices measured by the immersion method are:  $\alpha=1.752(5)$ ,  $\beta=1.770$  (calc.),  $\gamma=1.795(5)$ . It is optically biaxial negative,  $2V=85-90^\circ$ , dispersion  $r>v$ , strong. Anomalous birefringent colours are seen in some grains with smaller retardation. One of the characteristics of the present aegirine has an extremely small extinction angle with negative elongation, resembling clinzoisite.

### X-ray Study

The X-ray powder diffraction pattern is nearly identical with that of aegirine close to the ideal composition (FRONDEL and KLEIN, 1965) as compared in Table 1. The unit cell parameters calculated from the pattern are:  $a=9.645$ ,  $b=8.879$ ,  $c=5.290\text{\AA}$ ,  $\beta=107.28^\circ$ , which are very close to those of the compared material,  $a=9.657$ ,  $b=8.801$ ,  $c=5.291\text{\AA}$ ,  $\beta=107.44^\circ$ .

Table 1. X-ray powder diffraction pattern of aegirines from Narssarsuaq, Greenland and from the Kamisugai mine, Ehime Prefecture

1		2			hkl
I	d (Å)	I	d <sub>obs.</sub>	d <sub>calc.</sub>	
90b	6.369	100	6.370	6.363	110
80b	4.416	55	4.403	4.398	020
10	3.614	3	3.615	3.611	111
50	3.188	30	3.182	3.182	220
70b	2.983	65	2.981	2.981	22 $\bar{1}$
100	2.900	100	2.903	2.899	310
f	2.7920	5	2.793	2.794	130
50b	2.5408	15	2.542	2.544	13 $\bar{1}$
		12	2.525	2.525	002
60	2.4701	25	2.473	2.472	221
10	2.2530	5	2.255	2.256	311
30	2.1995	12	2.197	2.200	040
				2.198	112
30	2.1200	25	2.118	2.120	330
				2.116	33 $\bar{1}$
20	2.0943	10	2.092	2.092	12 $\bar{1}$
20	2.0101	12	2.016	2.017	014
f	1.9840				240
10	1.9350	8	1.934	1.934	24 $\bar{1}$
10	1.8818	5	1.879	1.880	51 $\bar{1}$
f	1.8263				331
10	1.8052	8	1.803	1.803	510
60b	1.7293	20	1.728	1.728	150
f	1.6590				042
f	1.6341	5	1.633	1.633	22 $\bar{3}$
50	1.6120	15	1.609	1.609	53 $\bar{1}$
50	1.592	20	1.590	1.590	440
10bb	1.5377	8	1.535	1.535	600
10bb	1.5290	15	1.526	1.527	350
				1.526	60 $\bar{2}$
				1.525	35 $\bar{1}$
20	1.4671	10	1.465	1.466	060
				1.465	152
60bb	1.3795	20	1.394	1.395	531
		10	1.375	1.376	223

1. Aegirine. Narssarsuaq, Greenland. After FRONDEL and KLEIN (1965). Camera method. Fe/Mn radiation.
2. Aegirine. Kamisugai mine, Ehime Prefecture, Japan. Fe/Mn radiation. Diffractometer method.

### Chemical Composition

The electron microprobe analysis made by Dr. T. YAMANAKA, Mineralogical Institute, University of Tokyo, is demonstrated in Table 2. The partial analysis for

Table 2. Electron microprobe analysis of aegirine from the Kamisugai mine, Ehime Prefecture, (\*: total iron)

	wt. %	Recast to 100%	Molecular quotient	Cation number	Oxygen number	Cation (O=6)
SiO <sub>2</sub>	52.37	52.25	0.8713	0.8713	1.7425	1.98
Al <sub>2</sub> O <sub>3</sub>	2.26	2.25	0.0221	0.0441	0.0662	0.10
TiO <sub>2</sub>	0.06	0.06	0.0008	0.0008	0.0015	0.00
Fe <sub>2</sub> O <sub>3</sub> *	27.81	27.75	0.1734	0.3475	0.5213	0.79
MgO	1.86	1.86	0.0461	0.0461	0.0461	0.10
MnO	0.14	0.14	0.0020	0.0020	0.0020	0.00
CaO	2.81	2.80	0.0501	0.0501	0.0501	0.11
Na <sub>2</sub> O	12.92	12.89	0.2080	0.4159	0.2080	0.95
Total	100.23	100.00				

Empirical formula:



Fe<sub>2</sub>O<sub>3</sub> by the third author gave 27.12% in weight together with the entire absence of FeO. The approximate composition of the present aegirine is Ac<sub>80</sub>Di<sub>10</sub>Jd<sub>10</sub>.

### Consideration on Genesis

In Japan are many localities of aegirine and aegirine-augite in contact or regionally metamorphosed bedded manganese or iron-manganese ore deposits, and all of them are found to contain MnO, ranging from 3.26 to 8.18 weight percent (NAMBU *et al.*, 1980), whereas the present aegirine is characterized by its extremely low MnO and absence of FeO despite its occurrence in iron and manganese ores.

Between such Mn<sup>2+</sup>-bearing and the present aegirines, one of the most significant difference is in the associated minerals, which reflect the degree of oxidation condition. That is, manganoan aegirines and aegirine-augites are generally accompanied by rhodonite. Under more oxidizing condition, a part of divalent manganese is oxidized into trivalent state, favouring the formation of braunite. In the dump of the Kamisugai mine, rhodonite is found in entirely different mineral association from that involving aegirine. Although the precise location of rhodonite-bearing association in the ore deposit is unknown, the prevalence of oxidizing condition was so local.

Since all the constituents in the present aegirine are in the ultimately oxidized states except for minor MnO, it can be taken as the terminal member to consider the compositional variation of aegirines and aegirine-augites found in metamorphosed manganese or iron-manganese ore deposits in Japan. The trend of variation is clearly given by NAMBU *et al.* (1980). Their compositions are plotted in the lower quarter portion in the triangular diagram (Mn<sup>2+</sup>, Fe<sup>2+</sup>)-Na-Mg diagram. But they take these components as apices and no variation in (Na+Ca)/(Mg+Fe<sup>2+</sup>+Mn<sup>2+</sup>+Fe<sup>3+</sup>+Al) or the ratio of larger cation to smaller one is indicated. The chemical

analyses of aegirines and aegirine-augites referred to by them demonstrate the slight excess of smaller cations and the corresponding deficiency of larger ones as a general tendency. Seeing from the radii of ions concerned, it is highly probable that a part of  $Mn^{2+}$  simulates a larger cation. In the present aegirine above ratio is very close to unity and no smaller cation simulating larger one. It is still uncertain whether this tendency is positively responsible for metamorphism or not, though johannsenite found in weakly metamorphosed skarn deposit of the Ohnagusa mine, Okayama Prefecture (MOMOI, 1964) contains excess of smaller cations and deficiency of larger ones, provided that no water contributes to the empirical formula.

Although the present conclusion requires the corroboration by the detailed structural analyses of pyroxenes concerned as well as the collection of more chemical and geological informations, the following genetical implications of the present aegirine can be independently deduced.

One is the exclusion of trivalent manganese to this aegirine. Despite its close coexistence with braunite, no trace of compositional influence due to trivalent manganese is found. At least, no participation of trivalent manganese to the aegirine structure is expected under the metamorphic condition that the present aegirine was formed.

The other is the presence of some jadeite molecule, which can be ascribed to the metamorphic condition, i.e., higher pressure and lower temperature one if the general conception applied to ordinary metamorphic pyroxenes can be hereby applied.

### References

- FRONDEL, C. & C. KLEIN, 1965. Ureyite,  $NaCrSi_2O_6$ , a new meteoritic pyroxene. *Science*, **149**: 742-744.
- MOMOI, H., 1964. Johannsenite from Teragōchi, Okayama Prefecture, Japan. *Mem. Fac. Sci. Kyushu Univ. Ser. D*, **15**: 65-72.
- NAMBU, M., K. TANIDA & T. KITAMURA, 1980. Chemical composition of manganese bearing pyroxene in Japan and its classification. *Jour. Miner. Soc. Japan*, **14**: Special issue (3), 117-128. (In Japanese).
- YOSHIMURA, T., 1969. Supplement to "Manganese Ore Deposits of Japan". Part II. Manganese Mines of Japan. *Sci. Rept. Fac. Sci. Kyushu Univ. Geol.* **9**: Special issue (2), 487-1004. (In Japanese.)