ALUMINIAN FERROANTHOPHYLLITE FROM THE KITAKAMI MOUNTAINLAND, NORTHEASTERN JAPAN

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ABSTRACT

Mineralogical and petrographical data for an aluminian ferroanthophyllite, a newly found variety of orthorhombic amphibole, unusually rich in iron and aluminium, are presented. The aluminian ferroanthophyllite was formed in a hornfels derived from an iron- and aluminium-rich pelitic rock of the lower Permian system through the contact metamorphism by the Tôno granodiorite mass in the southern Kitakami mountainland, northeastern Japan. Its chemical composition is represented by the formula

$$(K_{0.01}Na_{0.33}Mg_{0.01}Mn_{0.31}Fe''_{4.40}Fe'''_{0.35}Ti_{0.06}Al_{1.68})(Al_{1.97}Si_{6.03})(O_{21.79}OH_{2.15}F_{0.06})$$

which is very close to $Fe_5Al_2Si_6Al_2O_{22}(OH)_2$. This is far from the composition field of the anthophyllite series (including gedrite) as determined from the existing data. The unit cell dimensions of this mineral are $a=18.51_4$, $b=17.94_5$, $c=5.315_5$ Å, and its optical properties are $\alpha=1.694$, $\beta=1.710$, $\gamma=1.722$, $\gamma-\alpha=0.028$, $(-)2V=82°$, X: pale green, Y: brownish green, Z: greenish blue.

The existence of the continuous solid solution series between the aluminian ferroanthophyllite, $Fe_5Al_2Si_6Al_2O_{22}(OH)_2$, and the usual anthophyllite is discussed.

INTRODUCTION

How many atoms of iron and aluminium can enter into the unit cell of orthorhombic amphibole, i.e. anthophyllite (including gedrite), is an important problem. Many contributions to this problem were made by N. Sundius (1933) and others, whose chief interests, were directed, however, to the relation between the anthophyllite and cummingtonite-grunerite series. J. C. Rabbitt (1948) and others have shown that almost all the data for what were considered to be iron-rich members of the anthophyllite series were erroneous. Only three reliable determinations have an atomic ratio Fe/Mg higher than unity (1.28 is the highest value).

During the study of a metamorphic region in the Kitakami mountainland, northeastern Japan, one of the writers, Seki, found an anthophyllite having unusually high refractive indices and strong pleochroism. The writers' study have shown that this mineral is unusually rich in iron and aluminium, the composition being close to $Fe_5Al_2Si_6Al_2O_{22}(OH)_2$. In this paper the writers call this mineral aluminian ferroanthophyllite and they believe that the description of this mineral adds important data to the study of orthorhombic amphiboles.

The senior author is responsible for the petrographical and optical study, and the junior author for the chemical and x-ray portion. The detail of the petrology and geology of the metamorphic region are described separately by Seki (1957).

Mode of Occurrence

In the southern Kitakami mountainland, northeastern Japan, the upper Palaeozoic formations are widely distributed. These formations were intruded by several salic plutonic masses in Mesozoic time. The Tôno mass is one of the largest among these intrusives and is composed of hornblende-biotite granodiorite. Its contact aureole, 3 or 4 km. wide (Fig. 1), is divided into the following four progressive metamorphic zones on the basis of the mineral assemblages of pelitic hornfelses:

Chlorite-sericite zone: chlorite, sericite, chloritoid and chiastolitic andalusite.

Andalusite-biotite zone: andalusite, biotite and muscovite.

Cordierite-almandine zone: cordierite, almandine, anthophyllite, andalusite, biotite, muscovite, spinel and corundum.

Sillimanite zone: sillimanite, cordierite, almandine, biotite, muscovite, potash-feldspar, spinel and corundum.
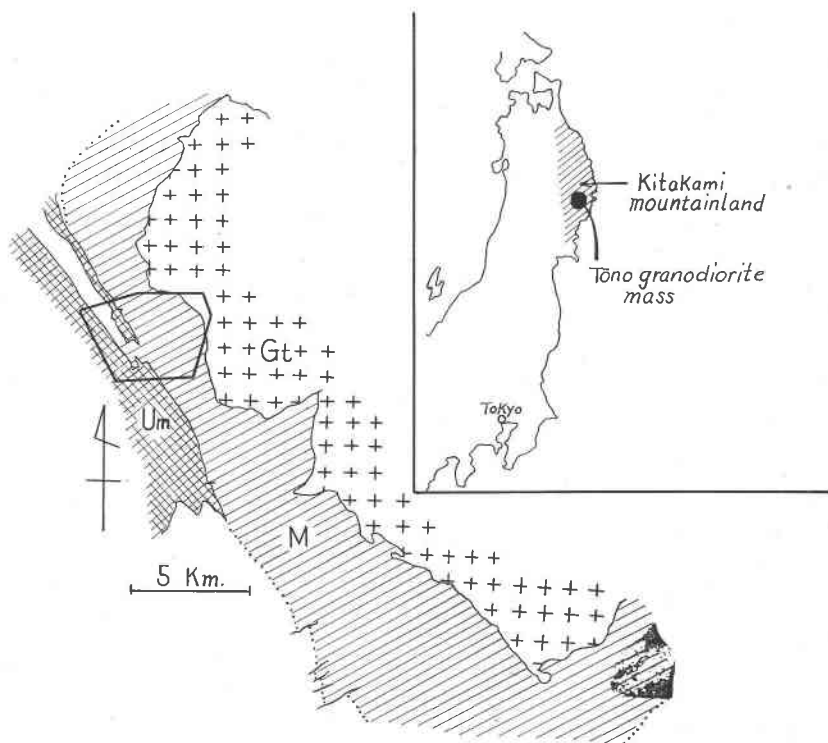

Fig. 1. Geological sketch map of the Tôno granodiorite mass and its contact aureole. The location of Fig. 2 is also shown on this map.

Gt = Tôno granodiorite mass.

M = Contact metamorphic aureole.

Um = Miyamori ultramafic mass probably intruded after the emplacement of the Tôno granodiorite and the formation of the associated metamorphic rocks.
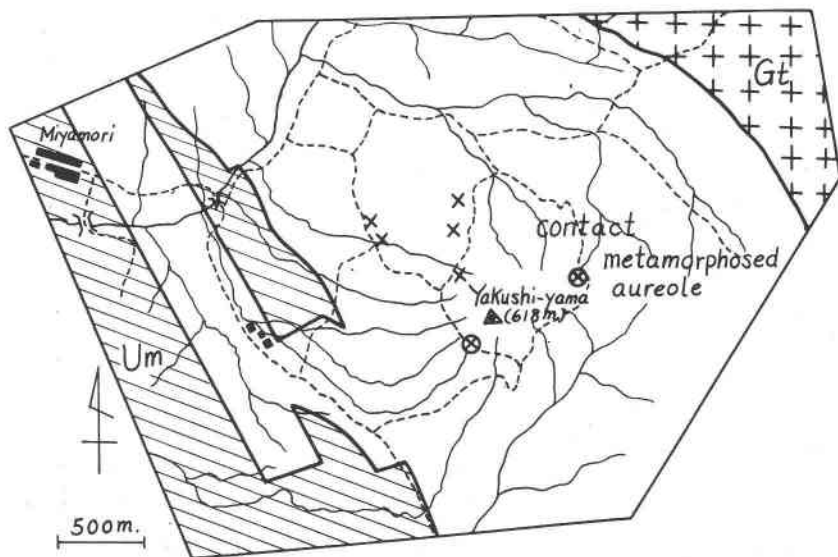
Fig. 2. Map showing the distribution of aluminian ferroanthophyllite-bearing horn-felses.

Gt = Tôno granodiorite mass.

Um = Miyamori ultramafic mass.

Encircled crosses = Outcrops of aluminian ferroanthophyllite-bearing hornfelses.

Crosses = Locations where only fragments of aluminian ferroanthophyllite-bearing horn-felses are found.

Anthophyllite including the aluminian ferroanthophyllite here described is found only in hornfelses derived from slate and tuffaceous slate and belonging to the cordierite-almandine zone.

The mineral parageneses of some anthophyllite-bearing hornfelses are shown in Table 1. In this table the optical properties of some minerals are also shown and the columns are arranged in the order of increasing refractive index γ of biotite.

It is seen in Table 1 and Fig. 3 that refractive indices of anthophyllite and cordierite generally increase with those of biotite. Anthophyllite, cordierite and biotite with comparatively high refractive indices are associated with spinel and almandine garnet.

The host rock of the analyzed aluminian ferroanthophyllite is a hornfels (Row 24 of Table 1; Sample number YS53041505) exposed on the western slope of Mt. Yakushi (618 m.) lying about 3 km. east of the village of Miyamori (Fig. 2). The hornfels is deep green, compact and massive, and has porphyroblastic crystals of the aluminian ferroanthophyllite. It contains segregations, several millimeters wide, composed chiefly

TABLE 1. MINERAL PARAGENESES OF ANTHOPHYLLITE-BEARING HORNFELSES IN THE CONTACT AUREOLE OF THE TÔNO GRANODIORITE MASS

Sample No.	Biotite	Cordierite		Anthophyllite				Garnet	Andalusite	Muscovite	Spinel	Corundum	Quartz	Plagioclase	Magnetite
	γ	γ	$(-)2V$	α	β	γ	$(-)2V$								
1. YS510 81912	—	1.534	n.d.	1.632	1.645	1.651	68°	−	−	+	−	−	+	+	+
2. YS510 81612	1.600	1.538	74°	n.d.	n.d.	1.665	74°	−	+	+	−	−	+	+	+
3. YS510 81922	1.604	1.535	68°–72°	1.641	1.652	1.660	72°	−	−	−	−	−	+	+	+
4. YS510 81817	1.614	1.542	88°	n.d.	n.d.	1.661	70°–81°	−	−	+	−	−	+	+	+
5. YS520 50711	1.616	1.542	74°	1.649	1.661	1.669	82°	−	+	+	−	−	+	+	+
6. YS510 81902	1.624	1.542	77°–84°	1.656	1.670	1.678	71°	−	+	+	−	+	+	+	+
7. YS500 81728	1.629	1.542	n.d.	1.658	1.670	1.677	78°	−	+	−	−	+	+	+	+
8. YS530 41415	1.630	1.551	n.d.	1.660	1.672	1.681	69°–72°	−	+	+	−	−	+	+	+
9. YS510 80705	1.630	1.548	88°	n.d.	n.d.	1.689	70°	−	−	+	−	−	+	−	+
10. YS540 42018	1.634	1.545	72°	1.668	1.682	1.689	74°	−	−	+	−	−	+	+	+
11. YS500 50603	1.635	1.550	n.d.	1.670	1.685	1.696	n.d.	−	+	+	−	−	+	+	+
12. YS501 01410	1.638	1.552	82°	1.668	1.682	1.689	80°–82°	−	+	+	−	−	+	+	+
13. YS540 42001	1.646	1.554	74°	1.676	n.d.	1.702	74°	−	+	+	−	+	+	+	+
14. YK540 42226	1.653	1.558	64°–82°	1.689	n.d.	1.717	72°	+	+	−	−	−	+	−	+
15. YS540 41417	1.654	1.553	75°–81°	1.684	n.d.	1.711	68°	−	+	−	−	−	+	+	+
16. YS530 41437	1.655	1.553	88°	1.680	1.692	1.703	74°	+	+	−	+	+	+	+	+
17. YS530 41223	1.657	1.558	80°	1.690	1.708	1.714	78°–80°	+	+	−	−	−	+	+	+
18. YS530 41212	1.660	1.558	75°	n.d.	n.d.	1.710	68°–82°	+	+	+	−	+	+	+	+
19. YS520 81231	1.659	1.552	64°–69°	1.683	1.692	1.705	70°–80°	+	+	+	+	−	+	−	+
20. YS530 41505A	1.660	1.567	n.d.	1.694	1.709	1.719	70°	+	+	+	−	+	+	−	+
21. YS530 41213	1.661	1.563	n.d.	1.697	1.710	1.722	68°	+	+	−	−	−	+	−	+
22. YS530 41501	1.664	1.564	n.d.	n.d.	n.d.	1.719	78°	+	+	−	−	−	+	+	+
23. YS530 41405	1.668	1.567	64°–69°	1.694	1.710	1.722	82°	+	+	+	+	−	+	+	+
24. YS530 41505	1.672	1.571	68°–75°	1.694	1.710	1.722	82°–84°	+	+	+	+	−	+	+	+

Note: Analyzed aluminian ferroanthophyllite was separated from the hornfels shown in row 24.
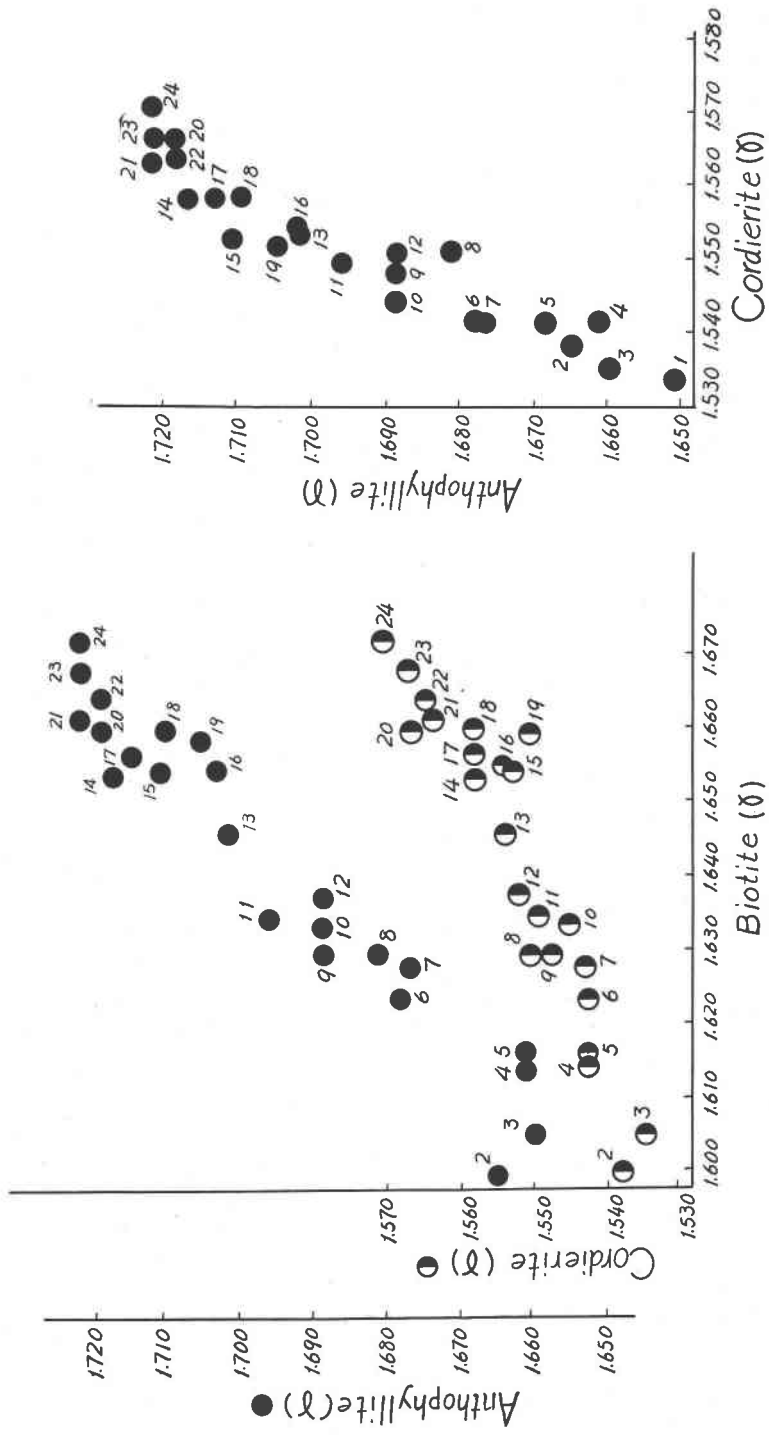
Fig. 3. Diagrams showing the relations between the indices of refraction of associated anthophyllite, biotite and cordierite in anthophyllite-bearing hornfelses of the contact aureole of the Tôno mass. The numbers refer to those of Table 1.

of the aluminian ferroanthophyllite and chlorite. The aluminian ferro-anthophyllite also occurs as a constituent of the matrix. No appreciable difference in optical properties is observed among the amphiboles of different modes of occurrence.

The porphyroblasts are in radiating forms attaining 1.3 cm. in length, and usually free from dusty inclusions of magnetite and graphite which are abundant in the crystals of the matrix. The matrix of the hornfels is composed of fine grained crystals of andalusite, cordierite, aluminian ferroanthophyllite, garnet, biotite, muscovite, spinel, plagioclase ($Ab_{37}An_{63}$), quartz, magnetite and graphite. Except garnet which sometimes reaches 1.4 mm. in diameter, these minerals are too fine grained to be distinguished from each other with the unaided eye.

The $Fe''/Mg+Fe''$ of the cordierite, estimated from its optical properties (Row 24, Table 1) using the diagram given by A. Miyashiro (1957, Figs. 2 and 3), is 0.80. This value is much higher than 0.582 for the cordierite described by H. H. Read (1929) which is the richest in iron among the cordierites ever described from metamorphic rocks. Such iron rich cordierites have been described only from pegmatites (H. Shibata, 1936).

Optical and chemical properties of the garnet are as follows: $n = 1.820 \pm 0.003$, $MnO = 0.42\%$, $FeO = 35.41\%$ (by weight).

Spinel, dark green in color, is always separated from quartz by a rim of cordierite, muscovite, biotite, and plagioclase.

The aluminian ferroanthophyllite in the segregation veins is associated with chlorite having the following optical properties:

$\alpha = 1.654 \pm 0.002$	$(-)2V =$ very small
$\beta = 1.660 \pm 0.002$	X: pale yellow
$\gamma = 1.662 \pm 0.002$	Y: dark olive green
$\gamma - x = 0.008$	Z: dark olive green

The x-ray powder diffraction data of the chlorite are as follows (Fe radiation):

hkl	I	θ
001	⌐20	3.94
002	100	7.90
003	25	11.90
004	70	15.97
005	10	20.06

Judging from these data the chlorite can be called thuringite.

The hornfels was analyzed by H. Kido (Table 2a). The rock is unusually rich in iron and aluminium. It is derived from pelitic rock of lower Permian. The lower Permian pelitic rocks of the southern Kitakami

TABLE 2. (a) CHEMICAL COMPOSITION OF THE HORNFELS (SAMPLE YS530 41505, TABLE 1)
CONTAINING THE ANALYZED ALUMINIAN FERROANTHOPHYLLITE
(b) CHEMICAL COMPOSITION OF A PELITIC ROCK OF THE LOWER PERMIAN
SYSTEM IN THE KITAKAMI MOUNTAINLAND. ANALYZED BY H. KIDO

(a)		(b)	
SiO_2	51.81	SiO_2	50.72
TiO_2	0.12	TiO_2	n.d.
Al_2O_3	27.87	Al_2O_3	24.01
Fe_2O_3	17.71	Fe_2O_3	7.21
FeO		FeO	10.02
MgO	1.16	MgO	0.98
CaO	0.57	CaO	0.97
Na_2O	0.35	Na_2O	0.81
K_2O	0.41	K_2O	1.21
H_2O+	0.16	Ig. Loss	4.11
H_2O-	0.57		
		Total	100.04
Total	100.73		

mountainland are occasionally rich in magnetite, probably of the detrital origin. An unmetamorphosed pelitic rock of the lower Permian, rich in iron and aluminium, was also analyzed (Table 2*b*). The richness in iron and aluminium and the poorness in magnesium and alkalies, especially of potassium, in the original pelitic rock, probably favored the formation of the aluminian ferroanthophyllite, spinel and almandine garnet.

MINERALOGICAL DESCRIPTION

Separation

The rock containing the anthophyllite with the highest refractive indices (YS53041505, Row 24 in Table 1) was crushed and the porphyroblasts were picked out under a magnifying-glass. By means of the isodynamic separator and heavy liquids, impure materials were removed, except a very small amount of thuringite and graphite. The thuringite could be eliminated by acid, but the writers did not do this as it might have affected the aluminian ferroanthophyllite itself. The effect of the contamination by graphite is negligible.

X-ray diffraction data

The *x*-ray powder diffraction data of the aluminian ferroanthophyllite were obtained by means of the Philips Geiger counter *x*-ray diffractometer using Fe radiation. Thirty-one peaks between 6° and 32° in angle θ were indexed on the basis of an orthorhombic unit cell with following

dimensions: $a_0 = 18.51_4$, $b_0 = 17.94_5$, $c_0 = 5.315_5$ Å. The data are listed in Table 3. Silicon powder was used as an internal standard. As this mineral is rich in iron, the peaks of the diffraction pattern are generally not so sharp as those of magnesian amphiboles. However, the difference between the observed and calculated values of angle θ does not exceed 0.02°. The result is in harmony with the symmetry of *Pnma* and almost all of the indices of the peaks in Table 3 correspond to those given by K. Johansson (1930). The figures of the unit cell dimensions do not show any remarkable differences from those given by many authors for the cell dimensions of ordinary anthophyllites, in spite of a remarkable difference in chemical composition.

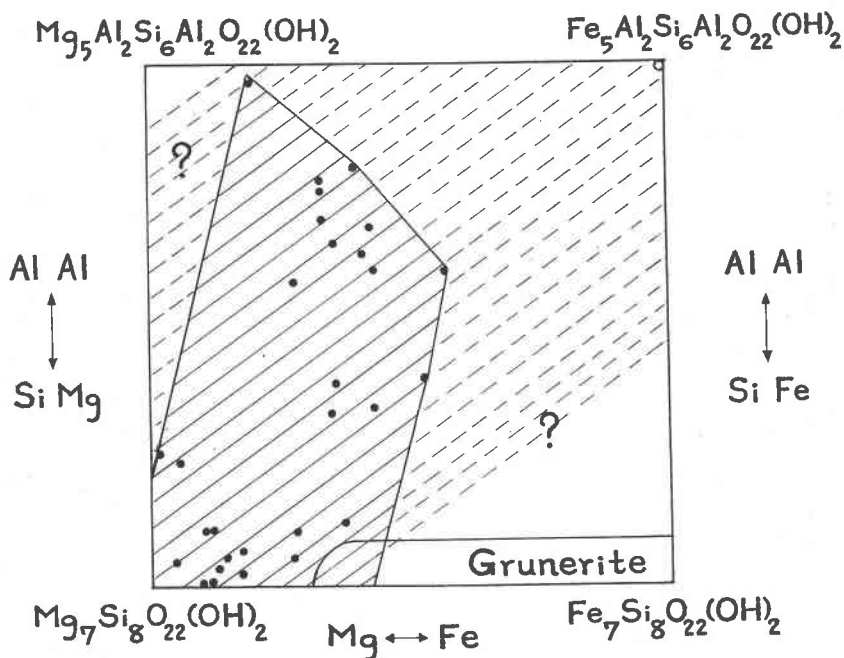Oscillation photographs about the *c* axis were taken by T. Iiyama us-

FIG. 4. The composition field of the anthophyllite series (including gedrite). The hatched area with full lines is determined from the data quoted by Rabbitt (1948). The area with broken lines is the possible field for this series. The field for the cummingtonite-grunerite series is also shown. In this diagram and also in Fig. 5 the point for each anthophyllite is plotted so that the degrees of the two ion substitutions, $(Mg,Fe)Si = AlAl$ and $Mg = Fe$, can be read from the vertical and horizontal axes, respectively. These diagrams should not be mistaken for ordinary square diagrams (Winchell, 1951, p. 7) in which the components at the corners would be $5Mg_7Si_8O_{22}(OH)_2$, $5Fe_7Si_8O_{22}(OH)_2$, $7Mg_5Al_2Si_6Al_2O_{22}(OH)_2$ and $7Fe_5Al_2Si_6Al_2O_{22}(OH)_2$.

TABLE 3. X-RAY POWDER DIFFRACTION DATA OF THE ALUMINIAN FERROANTHOPHYLLITE
FROM THE KITAKAMI MOUNTAINLAND

Index	Intensity	Angle θ for Fe radiation	
		Observed	Calculated
β(210)	23	6.13	6.13
020	12	6.21	6.19
210*	100	6.76	6.76
230*	3	11.12	11.11
400	10	12.07	12.07
040*	6	12.47	12.46
420*	4	13.63	13.61
131*	3	14.45	14.43
231	6	15.38	15.37
β(440)	5	15.84	15.84
β(610)	16	16.77	16.77
440*	21	17.50	17.49
610*	76	18.56	18.56
521*	5	19.65	19.66
260	3	19.89	19.88
251*	6	19.98	19.99
630*	3	20.67	20.67
351*	9	21.20	21.18
161*	9	22.04	22.03
202*	8	22.27	22.27
451*	9	22.75	22.76
302*	3	23.37	23.36
650	3	24.44	24.44
551*	4	24.68	24.67
502*	5	26.64	26.64
561*	3	27.01	27.01
661*	4	29.10	29.09
751*	3	29.32	29.32
670	3	29.41	29.40
702*	4	31.10	31.09
931	4	31.99	32.00

* Reflections given by Johansson (1930).

ing Fe radiation. The photographs provide a strong support for the idea that the crystal is orthorhombic. The upper and lower halves of the photographs separated by the zero-layer line show mirror image relation to each other. This fact indicates that the crystal has a symmetry plane perpendicular to the c axis. Thus not only the powder diffraction method but also the single crystal rotation method show that the crystal has orthorhombic symmetry.

In the powder diffractogram two peaks corresponding to $\theta = 7.90$ and 15.96 cannot be indexed as reflections from the aluminian ferroanthophyllite. They represent reflections from 002 and 004 of thuringite occurring as impurity in the aluminian ferroanthophyllite. These peaks disappear completely after treating the sample in hot dilute hydrochloric acid for half an hour. In the rotation photographs about the c axis the spots corresponding to the reflections of the basal planes of thuringite are observed on the zero-layer line. These facts taken in conjunction with the microscopic observation show that the thin flakes of thuringite are arranged with their basal plane parallel to the cleavage plane of the aluminian ferroanthophyllite.

Chemical composition

The separated sample of the aluminian ferroanthophyllite containing a small amount of thuringite was chemically analyzed by H. Haramura and its fluorine content was determined by M. Kamada. The results are given in Column A of Table 4.

In order to eliminate the effect of the contamination of thuringite, whose amount was estimated as 6% by weight of the analyzed sample, the chemical composition of the corresponding quantity of a thuringite from Steiermark (Hödl, 1941, p. 30) having optical properties similar to those of the thuringite in the analyzed sample, was subtracted from the bulk chemical composition. In Table 4, the chemical composition of the Steiermark thuringite is shown in Column B, and the calculated composition of the pure aluminian ferroanthophyllite is shown in Column C. The chemical composition of thuringite and the aluminian ferroanthophyllite are so similar and the quantity of the thuringite inclusions is so small, that the difference in chemical composition between the included and the Steiermark thuringites can be ignored.

In Table 5 are shown the atomic ratios of the aluminian ferroanthophyllite calculated on the basis of (O, OH, F) = 24. The aluminian ferroanthophyllite is unusually rich in iron and aluminium and is approximately represented by the formula $Fe_5Al_2Si_6Al_2O_{22}(OH)_2$.

TABLE 4. CHEMICAL COMPOSITIONS OF THE ALUMINIAN FERROANTHOPHYLLITE IN THE HORNFELS FROM SOUTHERN KITAKAMI MOUNTAINLAND, AND OF THURINGITE FROM STEIERMARK

	A	B	C
SiO_2	37.01	20.45	38.41
Al_2O_3	19.47	18.32	19.72
TiO_2	0.45	—	0.48
Fe_2O_3	2.57	8.46	2.21
FeO	33.51	37.78	33.54
MnO	2.16	0.26	2.30
MgO	0.19	2.69	0.03
CaO	0.03	—	0.03
Na_2O	1.08	—	1.16
K_2O	0.04	—	0.04
H_2O+	2.63	11.78	2.06
H_2O-	0.48	—	—
F	0.12	—	0.13
$-O=F_2$	0.05	—	0.06
Total	99.57		99.92

A: Chemical composition of the impure sample of the aluminian ferroanthophyllite containing 6% of thuringite impurity. Analyzed by H. Haramura and M. Kamada.
B: Chemical composition of thuringite from Rötzgraben, Steiermark (Hödl, 1941).
C: Chemical composition of the aluminian ferroanthophyllite calculated from A and B.

TABLE 5. THE ATOMIC RATIO OF THE ALUMINIAN FERROANTHOPHYLLITE CALCULATED ON THE BASIS OF (O, OH, F)=24

	Chem. comp.	Mol. prop.	Atomic ratio	
SiO_2	38.41	6395	Si	6.03 ⎫ 8.00
Al_2O_3	19.72	1936	Al	1.97 ⎭
TiO_2	0.48	60	Al	1.68 ⎫
Fe_2O_3	2.21	138	Ti	0.06 ⎪
FeO	33.54	4669	Fe'''	0.35 ⎪
MnO	2.30	324	Fe''	4.40 ⎪
MgO	0.03	7	Mn	0.31 ⎬ 7.15
CaO	0.03	5	Mg	0.01 ⎪
Na_2O	1.16	174	Ca	0.00 ⎪
K_2O	0.04	4	Na	0.33 ⎪
H_2O+	2.06	1144	K	0.01 ⎭
F	0.13	68	OH	2.15
$-O=F_2$	0.06		F	0.06
Total	99.92			

Optical properties

The optical properties of the aluminian ferroanthophyllite are as follows:

$$\alpha = 1.694 \pm 0.002 \qquad (-)2V = 82°, \, r < v$$
$$\beta = 1.710 \pm 0.002 \qquad X: \text{pale green}$$
$$\gamma = 1.722 \pm 0.002 \qquad Y: \text{brownish green}$$
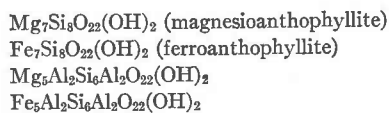$$\gamma - \alpha = 0.028 \qquad Z: \text{greenish blue}$$

M. Hey (1956) gave a set of partial regression equations for the refractive indices of anthophyllite. If we calculate the refractive indices of the aluminian ferroanthophyllite using the equations, the result is $\alpha = 1.7034$, $\beta = 1.7036$, $\gamma = 1.7193$. The deviations of these figures from those observed are probably due to the great difference in composition of the aluminian ferroanthophyllite from those used in deriving the equations.

Density

The density of the mineral is 3.56_6 as determined by suspending it in Clerici's heavy solution. The calculated value of the density based on the unit cell dimensions and the chemical composition is 3.56_2.

DISCUSSION

In orthorhombic amphiboles two kinds of ion substitution are important. One is the replacement of Mg by Fe and the other that of (Mg, Fe)Si by AlAl. From the existing data it appears that Al replaces Si up to a limit of two in eight ions, forming a partial solid solution series. Thus the composition of the orthorhombic amphiboles, i.e. the anthophyllite series, can be expressed as a solid solution composed of the following four components:

$$Mg_7Si_8O_{22}(OH)_2 \text{ (magnesioanthophyllite)}$$
$$Fe_7Si_8O_{22}(OH)_2 \text{ (ferroanthophyllite)}$$
$$Mg_5Al_2Si_6Al_2O_{22}(OH)_2$$
$$Fe_5Al_2Si_6Al_2O_{22}(OH)_2$$

The last two components represent the maximum replacement of Si by Al.

The diagram (Fig. 4) is constructed to show the composition field of the orthorhombic amphiboles, placing the above four components at the corners. The data used are those collected by J. C. Rabbitt (1948). The chemical composition of the aluminian ferroanthophyllite described in this paper is very close to the corner of $Fe_5Al_2Si_6Al_2O_{22}(OH)_2$ and is far off the composition field of the ordinary anthophyllite. The orthorhombic amphibole having the chemical composition of ferroanthophyllite proper, poor in aluminium, has not yet been found. The only amphibole having this composition is monoclinic grunerite. According to P. Eskola (1950),

the fields of the grunerite-cummingtonite series and anthophyllite series overlap with each other at least within a range of $Fe''/Mg+Fe''=0.31-0.40$ with little aluminium.

Judging from their optical properties, many anthophyllites listed in Table 1 have chemical compositions which fall between the analyzed aluminian ferroanthophyllite and the usual anthophyllite. Thus there exists a continuous solid solution series between them. Anthophyllites close to $Mg_5Al_2Si_6Al_2O_{22}(OH)_2$ have not been found yet. But it is possible, if not probable, that a continuous solid solution series exists throughout the area of the diagram except in the iron rich part of the cummingtonite-grunerite series as has been suggested by Sundius (1933).

A. N. Winchell (1951, p. 427) constructed a diagram which shows the relation between the refractive index γ and the chemical composition of the anthophyllite (gedrite) series rich in magnesium. He expressed the solid solution using the above four components as end members. Fig. 5 shows a diagram which extends Winchell's diagram to the field rich in iron and aluminium. The lines for the refractive index γ are located by
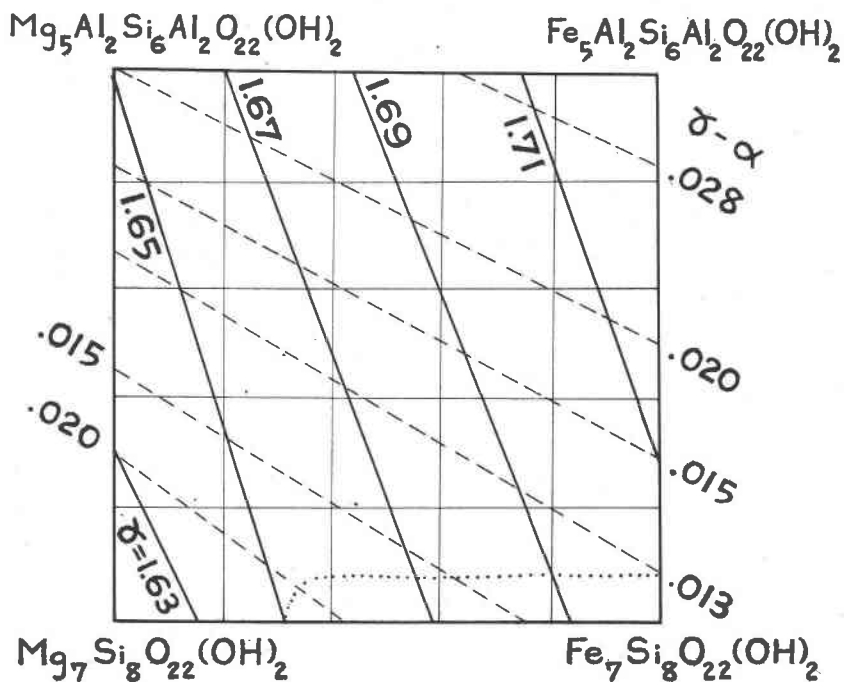

FIG. 5. Relation between optical properties and chemical composition of the anthophyllite series. See the explanation of Fig. 4.

means of interpolation. In this diagram is also shown the relation between the amount of double refraction and the chemical composition. The amount of double refraction is minimum in the intermediate range of the (Mg, Fe)Si-AlAl substitution. No systematic relation is found between the chemical composition and the optic axial angle.

The name ferroanthophyllite was first used by E. V. Shannon (1921) for a mineral erroneously determined as an iron rich variety of anthophyllite. A. N. Winchell (1933) called the hypothetical iron end member of the anthophyllite series ferroanthophyllite and the type high in aluminium gedrite. However, according to the system of nomenclature proposed by W. T. Schaller (1930), the name gedrite which represents a member of a partial solid solution series should not be used. The atomic ratio Al (in tetrahedral position):Si of the amphibole described in this paper is not greater than unity. So it is appropriate to call this amphibole "aluminian ferroanthophyllite."

REFERENCES

ESKOLA, P., 1950, Paragenesis of cummingtonite and hornblende from Muuruvesi, Finland: *Am. Mineral.*, **35**, 728–734.

HEY, M., 1956, On the correlation of physical properties with chemical composition in multivariate systems: *Mineral. Mag.*, **31**, 69–95.

HÖDL, A., 1941, Über Chlorite der Ostalpen, ein Beitrage zur Systematik der Chlorite: *Neues Jahrb. B. Bd.*, **77**, 1–77.

JOHANSSON, K., 1930, Vergleichende Untersuchungen an Anthophyllit, Grammatit und Cammingtonit: *Zeits. Krist.*, **73**, 31–51.

MIYASHIRO, A., 1957, Cordierite-indialite relations: *Am. Jour. Sci.*, **255**, 43–62.

RABBITT, J. C., 1948, A new study of the anthophyllite series: *Am. Mineral.*, **33**, 263–323.

READ, H. H., 1929, On the occurrence of iron-rich cordierite in Aberdeenshire: *Geol. Mag.*, **66**, 547–552.

SEKI, Y., 1957, Petrological studies of hornfelses in the central part of the median zone of Kitakami mountainland, Iwate Prefecture, Japan: *Sci. Rept. of the Saitama University*, **2**, no. 3 (in press).

SCHALLER, W. T., 1930, Adjectival ending of chemical elements used as modifiers to mineral names: *Am. Mineral.*, **15**, 566–574.

SHANNON, E. V., 1921, Description of ferroanthophyllite from Idaho, with a note on the nomenclature of the anthophyllite group: *U. S. National Museum, Proc.*, **59**, 397–401.

SHIBATA, H., 1936, Graphic intergrowth of cordierite and quartz in pegmatites from Sasago and Dosi, Province of Kai, Japan: *Japanese Jour. Geol. and Geog.*, **13**, 205–229.

SUNDIUS, N., 1933, Über die Mischungslücken zwischen Anthophyllit-Gedrit, Cummingtonit-Grünerit und Tremolit-Aktinolith: *Tschermak's Min. Petr. Mitt.*, **43**, 422–440.

WINCHELL, A. N., 1933, Elements of Optical Mineralogy, Part 2, 3rd edition: John Wiley & Sons, Inc. New York.

——, 1951, Elements of Optical Mineralogy, Part 2, 4th edition: John Wiley & Sons, Inc. New York.

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