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An Amphibole Built up from Two Different Lattices

By

Tateo UEDA and Katsutoshi TOMITA

Geological and Mineralogical Institute, University of Kyoto

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Abstract

An amphibole from Ibaraki City, Japan is built up from two different lattices, viz., $C2/m$ and $I2/m$. The two lattices are associated in such a way as their *b*- and *c*-axis directions are in common respectively.

Introduction

T. ITO (1950) pointed out that the structure of anthophyllite (*Pnma*) could be regarded as a twinned monoclinic amphibole the space group of which was $P2_1/m$, although such an amphibole had not been found. Since then, mineralogists have been much interested in the space group of cummingtonite-grunerite series. Anthophyllite is usually *Mg*-rich and its composition with more than about 40 percent of $Fe_7Si_8O_{22}(OH)_2$ end-member has not been found. Cummingtonite-grunerite series is usually *Fe*-rich, however, its composition with more than about 70 percent of Mg_7-$Si_8O_{22}(OH)_2$ end-member has been reported. Recently the authors have got an amphibole the $Mg_7Si_8O_{22}(OH)_2:Fe_7Si_8O_{22}(OH)_2$ ratio of which is approximately 1 : 1. With the amphibole the authors have made a lattice analysis and it has been found that the mineral is built up from two different lattices, viz., $C2/m$ and $I2/m$. In the following details will be given.

Occurrence

At the northern part of Ibaraki City in Central Japan there crop out igneous rocks such as granodiorite, granite porphyry which come into contact with Palaeozoic Formations. In the Palaeozoic Formations and close to the contact zone, which consists mainly of siliceous hornfels, there is a lens-like mass, about 10 *m* in length and about 1.5 *m* in width of its middle part, composed mainly of quartz and amphibole. (Fig. 1) The two minerals are not intimately mixed each other. The amphibole is grouped in masses which are irregular in shape and variable in size consisting of fibrous crystals

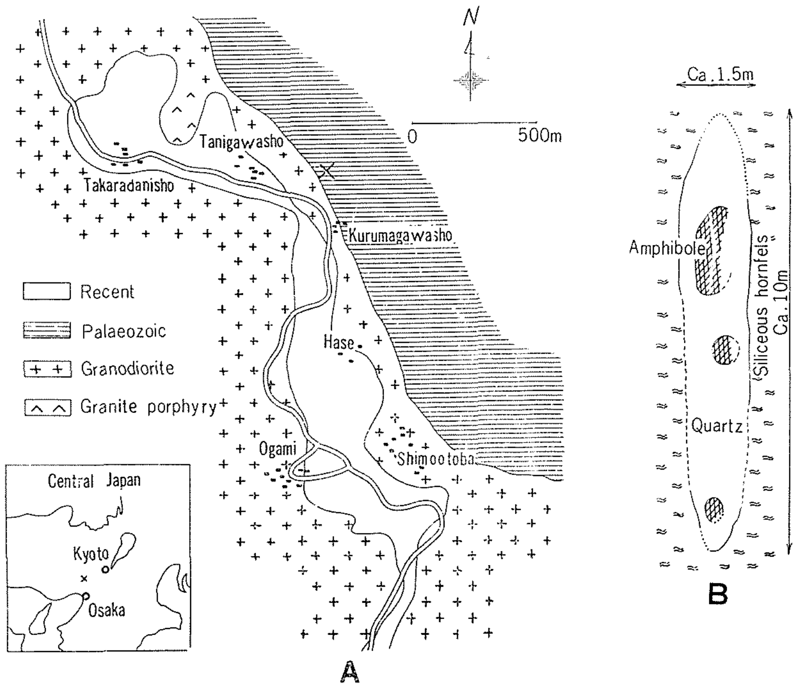

Fig. 1. A. Geological sketch, locality is marked by ×.
B. Mass, consisting of quartz and amphibole.

oriented in nearly the same direction. Platy crystals of ilmenite are frequently inserted in the amphibole masses. Biotite and microcline are also the constituents of the lens-like mass, although they are very scanty in amount.

Experimental

The amphibole is vitreous in luster, grayish green to dark green in colour, pale whitish yellow in streak. $H=5.5$, $G=3.20$. The mineral is perfectly homogeneous under the microscope. The characteristic cleavages crossing at about 55° in a thin section perpendicular to c-axis are highly distinct. Optical properties are as follows:

$$n_\alpha = 1.652$$
$$n_\beta = 1.664$$
$$n_\gamma = 1.680$$

Absorption, $Z > Y > X$

Optic plane, (010)

$Z \wedge c$-axis, 10° to 25° in the obtuse angle β

$$2V_\gamma = 82^\circ \ (+)$$

The chemical composition and the number of cations on a basis of 24 oxygens, calculated from the percentages of the constituents, are shown in Table 1.

Table 1. Chemical composition.

Constituent	Percentage by weight	Number of molecules	Number of oxygens	Number of cations on a basis of 24 oxygens	
SiO_2	51.19	0.852	1.704	7.65	7.76
Al_2O_3	0.59	0.006	0.018	0.11	
TiO_2	0.27	0.003	0.006	0.03	7.22
Fe_2O_3	2.99	0.019	0.057	0.34	
FeO	24.87	0.346	0.346	3.11	
MnO	0.39	0.005	0.005	0.04	
MgO	14.56	0.361	0.361	3.24	
CaO	2.43	0.043	0.043	0.39	
Na_2O	0.16	0.003	0.003	0.05	
K_2O	0.12	0.001	0.001	0.02	
$H_2O^{(+)}$	2.31	0.128	0.128	2.30	2.30
$H_2O^{(-)}$	0.32				
Total	100.20				

Hence the chemical formula; $(Mg, Fe)_7Si_8O_{22}(OH)_2$,
and $Mg_7Si_8O_{22}(OH)_2$: $Fe_7Si_8O_{22}(OH)_2$; approximately 1 : 1.

The mineral might be identified as cummingtonite from the viewpoints of the optical properties and the chemical composition. The X-ray powder pattern of the mineral is, however, somewhat different from that of cummingtonite. The authors, therefore, tried to examine the mineral in detail taking Weissenberg photographs.

Rotation and Weissenberg photographs about c-axis were taken with slender cleavage splinter using Fe-K_α radiations. In the rotation photograph all the spots are arranged perfectly on the layer lines. In the zero layer Weissenberg photograph the arrangement of the spots is the same as that in the case of tremolite. (Fig. 2) In the 1st and 2nd layer equi-inclination Weissenberg photographs the arrangements of the spots are, however, quite different from those in the case of tremolite. (Fig. 3, Fig. 4) Examining the reciprocal lattice rows on the 1st and 2nd layer equi-inclination Weissenberg photographs, it was found that there were two sets of spots, one set of spots being less abundant in number than the other. It follows immediately from these facts that the mineral is composed of two component lattices, the *hk0* reciprocal net planes of the two component lattices being common and the c-axes of the direct lattices being parallel in direction and identical in length. In Fig. 5 are shown the zero, 1st

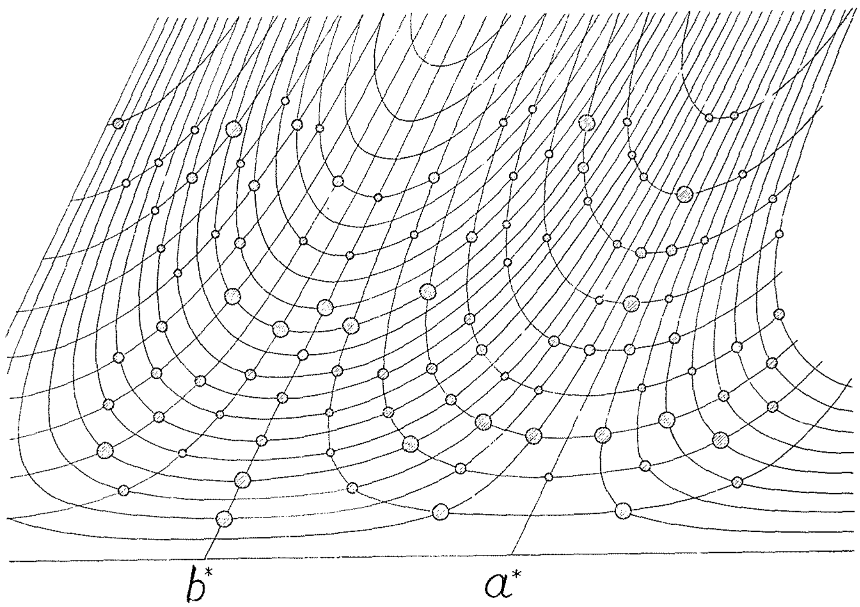

Fig. 2. *hk0* Weissenberg diagram.

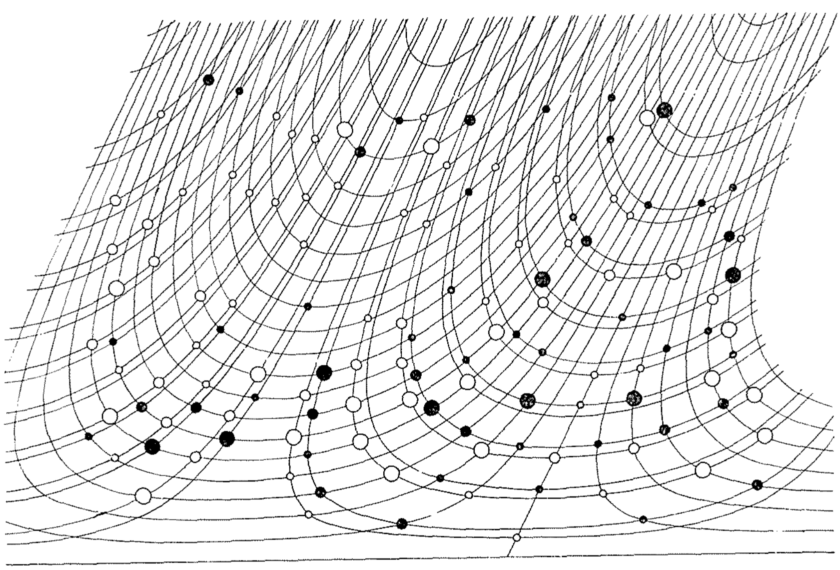

Fig. 3. *hk1* equi-inclination Weissenberg diagram.

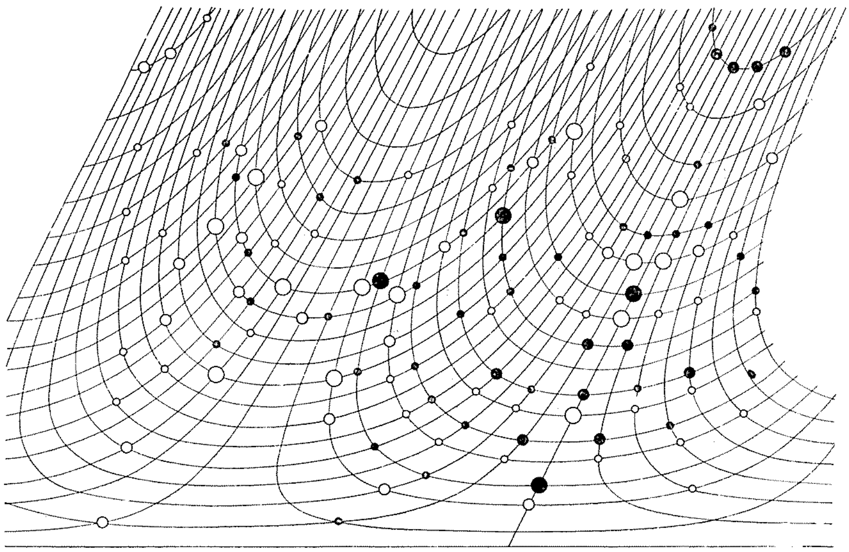

Fig. 4. *hk2* equi-inclination Weissenberg diagram.

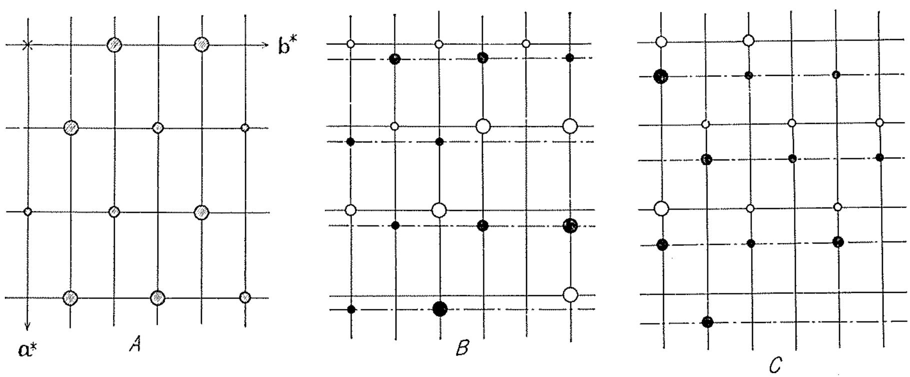

Fig. 5. Reciprocal net planes. A. *hk0* net plane, B. *hk1* net plane, C. *hk2* net plane.

and 2nd level reciprocal lattice planes derived from the zero layer Weissenberg and the 1st and 2nd layer equi-inclination Weissenberg photographs respectively.

Setting the reciprocal axes as a^*, b^* in Fig. 2 and Fig. 5-A, in one lattice *hkl* reflexions appear when $h+k=2n$, *h0l* reflexions when $h=2n$ and *0k0* reflexions when $k=2n$, hence $C2/m$, while in the other lattice *hkl* reflexions appear when $h+k+l=2n$, *h0l* reflexions when $h+l=2n$ and *0k0* reflexions when $k=2n$, hence $I2/m$. The two reciprocal lattices are in such a relationship as their a^* and b^* axes directions are the

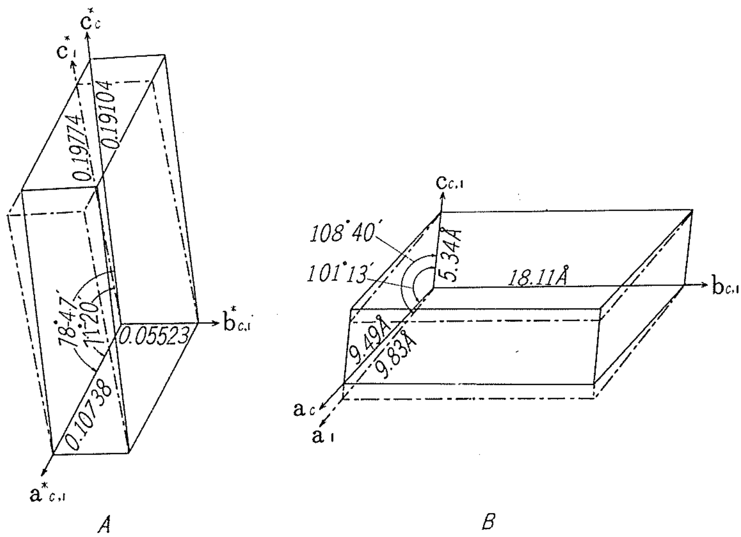

Fig. 6. Relationship between two component lattices.
A. Reciprocal lattices, B. Direct lattices.

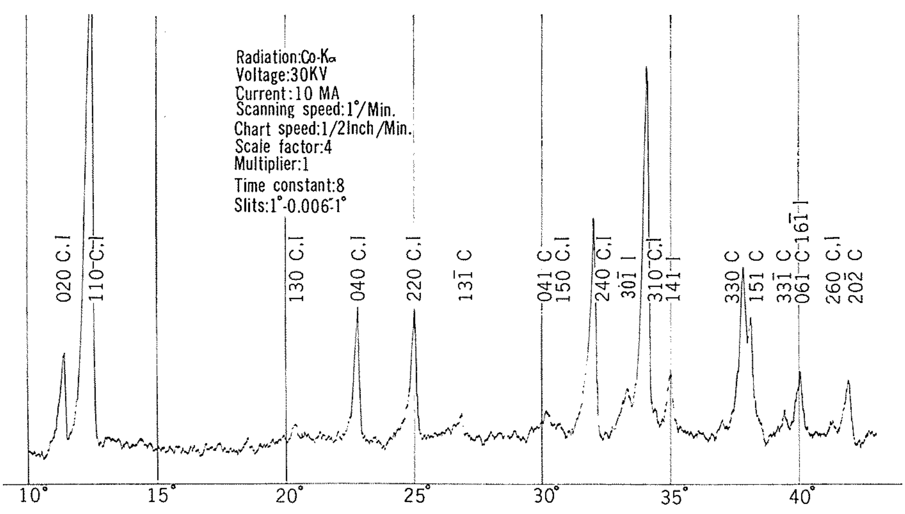

Fig. 7. X-ray powder pattern.

same respectively and their c^* axes make an angle of 7°27′ each other. (Fig. 6-A) The lattice dimensions and the axial angles of the two component lattices are as follows:

$C2/m$	$I2/m$
$a=$ 9.49±0.01 Å	$a=$ 9.83±0.01 Å
$b=$18.11±0.01 Å	$b=$18.11±0.01 Å
$c=$ 5.34±0.01 Å	$c=$ 5.34±0.01 Å
$\beta=$101° 13′±0.1°	$\beta=$108° 40′±0.1°

The two component direct lattices are associated in such a way as their b- and c-axis directions are in common respectively. (Fig. 6-B) They may probably be arranged side by side.

The X-ray powder pattern of the present mineral, to which the authors previously failed in giving indices using the cell-dimensions and the axial angles of cummingtonite determined by S. GHOSE (1961), can be irreproachably indexed using the cell-dimensions and the axial angles of the two component lattices as will be seen in Fig. 7, in which 'C' denotes the reflexion brought about by C-lattice and 'I' the reflexion by I-lattice.

Consideration

The amphibole from Ibaraki City is built up from two different lattices, viz., $C2/m$ and $I2/m$. $I2/m$, however, can be transformed to $C2/m$ and *vice versa*. Provided that $I2/m$ is transformed to $C2/m$, the result is that which illustrated in Fig. 8 by dotted lines. The cell-dimensions and axial angles of the two lattices, original C-lattice and

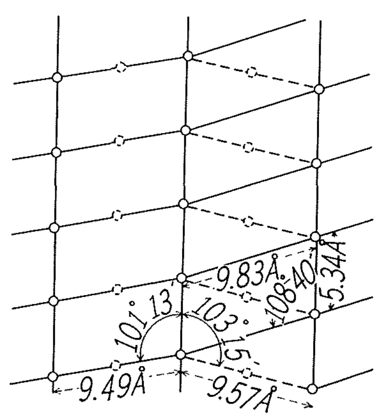

Fig. 8. Relationship between two component lattices, showing C-lattice derived from I-lattice by dotted lines.

the C-lattice obtained by transforming I-lattice are as follows:

$C2/m$	$C2/m$ from $I2/m$
$a=$ 9.49 Å	$a=$ 9.57 Å
$b=$18.11 Å	$b=$18.11 Å
$c=$ 5.34 Å	$c=$ 5.34 Å
$\beta=101°13'$	$\beta=103°15'$

Accordingly, the amphibole from Ibaraki City may be thought as a twin on a unit cell scale, the space group of the component halves is $C2/m$ ($I2/m$); but not $P2_1/m$, although the component halves of the twin are not exactly the same.

Acknowledgment

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