MUSCOVITE FROM METHUEN TOWNSHIP, ONTARIO*

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ABSTRACT

Muscovite crystals from Methuen Township, Ontario, have {001}, {110} and {$\bar{1}$11} as dominant forms; also present are {111}, {010}, {021}, {$\bar{1}$12}, {112}, {011} and {021}. Penetration twins with twin axis [310] are common. Optically (−) with $nX_{,}=1.5595$, $nY=1.5930$, $nZ=1.5991$; $X:c=4°33'$, $Y=b$, $2V=45°38'$. Unit cell dimensions: $a_0=5.18$Å, $b_0=8.99$, $c_0=20.01$, $\beta=96°$. Specific gravity 2.84 (meas. and calc.). Chemical analysis: SiO_2 45.87, Al_2O_3 38.69, MgO 0.10, Na_2O 0.64, K_2O 10.08, H_2O 4.67; total 100.05.

INTRODUCTION

In 1944 Dr. Hugh S. Spence collected about 200 specimens of diamond shaped muscovite crystals from Blue Mountain, Methuen Township, Ontario. The muscovite was found in a narrow pegmatite dike that cuts transversely through the country rock bordering the large Blue Mountain mass of nepheline syenite. These crystals were in that portion of Dr. Spence's collection acquired by Harvard University. Because of their remarkable physical properties, it was felt that these crystals deserved special study.

Most of the specimens are aggregates of several crystals but others are single crystals that range in size from two to twenty centimeters along the longest diagonal and up to eight centimeters thick. There are several properties that immediately attract the attention. These are: the remarkable transparency both normal to and parallel to the cleavage, twinning, and the high rigidity of even thin cleavage pieces.

CRYSTALLOGRAPHY

Over half of the muscovite crystals have a simple habit with *c* {001}, *m* {110} and *p* {$\bar{1}$11} the only forms present. Others, however, may have at least one face of seven or eight different forms. Many faces are of high quality and could be measured on the reflecting goniometer but the large size of the crystals makes such measurements difficult. However, sufficiently accurate measurements can be made with the contact goniometer to permit identification of the forms. According to the crystallographic orientation of muscovite given by Peacock and Ferguson (1943), the following forms, in order of decreasing frequency, have been observed: *c* {001}, *m* {110}, *p* {$\bar{1}$11}, *o* {111}, *b* {010}, *y* {021}, *h* {$\bar{1}$12}, *ε* {112}, *e* {011}, *y* {021}. This form development does not agree well with the theoretical order of form importance based on the order of de-

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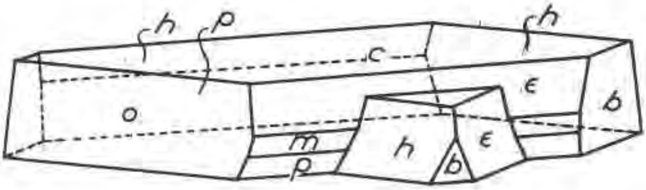

FIG. 1. Twinned muscovite crystal, Methuen Township, "Left" twin.

creasing spacing as given by Peacock and Ferguson (1943) in which decreasing order should be *cbm pyo heε*.

About one third of the crystals are twinned according to the "mica law." The obvious evidence of this is triangular projections from the sides of the crystals as shown in Fig. 1. The two or three individuals in twin position may be of equal size (Fig. 2); or, as is more generally the case, one may be greatly subordinate to the other, for a crystal 100 millimeters on the long diagonal may have a projecting twin only 5 millimeters long.

Peacock and Ferguson (1943) in discussing twinning in muscovite state that it "—commonly forms twins in which the two individuals are in contact on a common plane *c*(001) and symmetrical by reflection in a plane (*hhl*) which is perpendicular to *c*(001). Reflection in (*hhl*) gives a "right" twin which is distinct from a "left" twin resulting from reflection in ($h\bar{h}l$)." They more rigorously define the twin element as the axis [310] in the plane (001). And they finally state that "The twin law of muscovite is thus correctly and uniquely defined as: 'twin axis [310], composition plane (001).' "

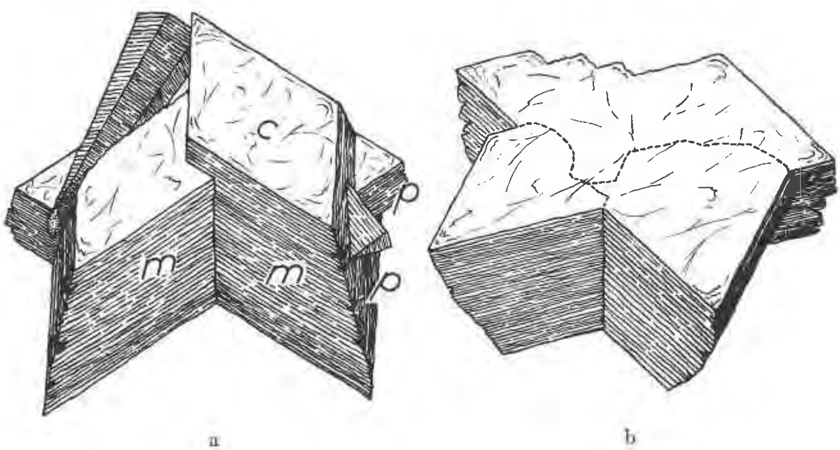

FIG. 2. Top (*a*) and bottom (*b*) of twinned muscovite group showing "right" and "left" twins.

The above *law* states precisely the geometrical relationship between the individuals of the twins here described, for a rotation of 180° about [310] produces the observed relations with (001) of both individuals coplanar. However, these twins do not conform to that part of the *law* that states that the composition plane is *c*(001), if we consider *composition plane* in the usual sense, namely, the plane on which the two individuals are united. The contact surface is highly irregular but roughly at right angles to (001). It is a penetration rather than a contact twin. To cover both types of twinning, the twin law of muscovite can be defined merely as: "twin axis [310]." In Fig. 2*b* the dotted lines indicate the boundaries in the (001) plane between the three individuals.

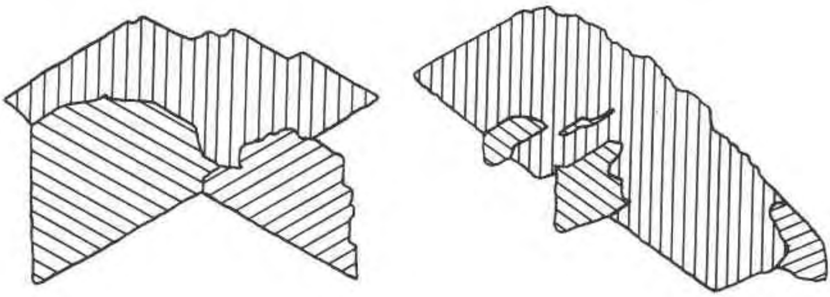

FIG. 3. Cleavage flakes of muscovite twins. The lines parallel the trace of the symmetry plane.

In some respects this twinning in muscovite is similar to Brazil twinning in quartz for which there may be no morphological evidence and small volumes of one individual may be completely surrounded by the other individual as host. Brazil twinning can be detected optically in sections cut parallel to (0001) and hence is called "optical twinning." By analogy this might be called "optical twinning" in mica for between crossed polarizers the different orientation of the extinction positions can be seen easily (Fig. 3).

In order to trace the twin portion, a muscovite crystal 15 millimeters thick was cleaved at approximately one millimeter intervals and twinned portions determined optically. Successive sections through this crystal are shown in Fig. 4. The only morphological evidence of twinning here was the small triangular projection at the bottom of the crystal. Other crystals lack even this evidence but optical examination shows small portions to be in twinned position.

PHYSICAL PROPERTIES

Most of the Methuen Township muscovite crystals have a pearly luster on (001) and are transparent only in relatively thin cleavage

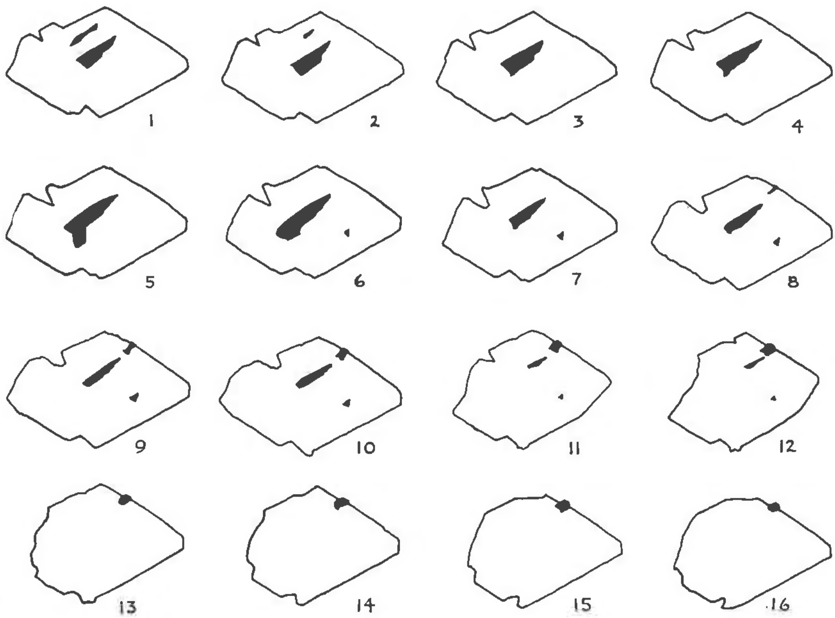

Fig. 4. Successive cleavage sections one millimeter apart through a twinned muscovite crystal. Dark areas indicate portion in twinned position.

flakes. A few, however, are remarkable for their clarity and transparency. Crystals a centimeter thick are water clear and resemble more a cleavage piece of selenite than of mica. Some of the crystals are quite transparent and the remainder at least semi-transparent when viewed parallel to the cleavage. In this direction the color is pale green.

The highly transparent crystals require considerable pressure with the knife edge to develop the cleavage but once started the cleavage extends completely across the crystal as a plane surface. On one such crystal, ten centimeters in maximum dimension, the cleavage surfaces were found to be plane within one-half a wavelength of sodium light.

The Methuen Township muscovite has a measured specific gravity of 2.84 (calculated 2.84). This same value was determined by hydrostatic weighing of a 19 gram crystal, by suspension in bromoform and by means of the Berman balance.

Optical Properties

Because of the high degree of transparency of many of the crystals parallel to (001), it was felt that a prism might be cut from one of them for measuring the refractive indices by the method of minimum deviation. Accordingly, on a crystal two centimeters thick two faces were cut and polished by the Jones Optical Company of Cambridge, Massachusetts. The faces, at about 60° to one another, were cut normal to (001) and oriented so that [010] bisected the angle between them. The cutting developed some incipient cleavage planes but for a thickness of three millimeters the prism remained flawless. This portion of the prism was used to measure the refractive indices in the X and Z directions. The value for nY was determined by the Emmons (1943) double variation method. The value obtained for nZ by this method checked that obtained with the prism by the method of minimum deviation.

Tschermak (1878) noted that the acute bisectrix in muscovite makes an apparent angle of −0°30′ to −1°44′ with the cleavage normal. Ferguson (1943) confirmed these observations and determined this angle as −1°14½′ for muscovite from Mattawan Township, Ontario. Using the simple and ingenious method described by Ferguson, the apparent angle between the acute bisectrix and the cleavage normal for the Methuen Township muscovite was determined as −1°45′. This gives a true angle of −1°06′. Accepting the angle [001]$\wedge$[100] of 95°39′ as given by Peacock and Ferguson (1943), X$\wedge c$[001] = 4°33′.

The apparent optic axial angle (2E), determined using the optic axial angle goniometer with sodium light, was found to be 76°15′. This gives the true axial angle (2V) as 45°38′. As calculated from the measured refractive indices, 2V = 45°26′.

TABLE 1. OPTICAL PROPERTIES OF MUSCOVITE, METHUEN TOWNSHIP

	n_{Na}		
X $\wedge c$ = 4°33′	1.5595	±0.0003	Opt. (−)
Y	1.5930		2V = 45°38′ (Na)
Z = b	1.5991		$r > V$

UNIT CELL AND CHEMICAL COMPOSITION

A thin cleavage flake which was brought to a sharp point by the bounding faces (110) and ($\bar{1}$11) was used for rotation and Weissenburg photographs rotating about the symmetry axis. Another set of photographs was taken rotating about the pseudo-a axis lying in (001). The cell dimensions obtained from the zero layer Weissenburg photographs are as follows: a_0 = 5.18 Å, b_0 = 8.99 Å, c_0 = 20.01 Å, β = 96°. The systematic omissions of the zero and first layer line Weissenburg photographs lead to the space group $C2/c$, which confirms the space group given by Mauguin (1927), Jackson and West (1930) and Ferguson (1943).

Hendricks (1939) in his study of micas determined seven different polymorphic types and showed that all species with the exception of muscovite existed in two or more modifications. Muscovite he found to occur only in the two-layer (2*M*) structural type. This has been called "normal muscovite" by Heinrich *et al.* (1953). Axelrod and Grimaldi (1949) report an exception and describe a three-layered muscovite (3*M*) from Snohomish County, Washington. The Methuen Township muscovite is the normal two-layer type.

Table 2. Chemical Analysis and Unit Cell Contents of Muscovite

	1	2	3	Atomic Proportions	Experimental Cell Contents×1594/100*	
SiO_2	45.27	45.87	45.85	.7645	Si —12.18	16.00
Al_2O_3	38.39	38.69	38.67	.7381	Al —11.76	
MgO		0.10	0.10	.0025	Mg— 0.04	7.98
Na_2O		0.64	0.64	.0206	Na — 0.33	3.74
K_2O	11.82	10.08	10.07	.2140	K — 3.41	
H_2O	4.52	4.67	4.67	.5189	OH— 8.27	48.04
F		None			O —39.77	
	100.00	100.05	100.00			

1. $KAl_2(AlSi_3)O_{10}(OH)_2$.
2. Methuen Township muscovite. Analysis by F. A. Gonyer.
3. #2 recalculated to 100 per cent.

* The molecular weight of the unit cell contents obtained using the cell volume, 932 Å^3 and specific gravity, 2.84.

A portion of one of the water-clear, flawless crystals was selected for chemical analysis. The analysis, carried out by standard methods, was preceded by a spectrographic analysis which showed traces of Ca, Fe, Li and Mn. The results of the chemical analysis are given in Table 2 with the theoretical weight percentages of $KAl_2(AlSi_3)O_{10}(OH)_2$ for comparison. It will be noted that the composition of the Methuen Township muscovite approaches very closely the theoretical. This is shown also by a comparison of the following structural formulas:

Ideal formula—$4[KAl_2(AlSi_3)O_{10}(OH)_2]$
Muscovite, Methuen Township from Table 2—
$4[(K, Na)_{0.94}(Al, Mg)_{1.99}(Al_{0.95}Si_{3.05})O_{9.94}(OH)_{2.07}]$

Acknowledgments

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