

# STUDIES IN THE MICA GROUP; POLYMORPHISM AMONG THE HIGH-SILICA SERICITES

E. WM. HEINRICH AND A. A. LEVINSON,

*Departments of Mineralogy,  
University of Michigan\* and The Ohio State University,  
Ann Arbor, Michigan, and Columbus, Ohio.*

## ABSTRACT

X-ray studies on the high-silica sericites indicate that alurgite crystallizes as the *3T* and *2M* polymorphs, that mariposite crystallizes as the *2M* and *1M* polymorphs, and that material called phengite (including sericite) has crystallized as *3T*, *2M* and *1M* polymorphs. The *3T* and *2M* polymorphs have been found intimately associated and have in some specimens formed within the same mica sheet. The precise chemical nature of the individual types is obscure, inasmuch as most of the available analyses have been obtained on samples of mixed structural types. Micas of these types with  $2V$  moderate have the *2M* structure; if  $2V=0$ -small, the structure is *3T* for well developed crystals of phengites and alurgites and *1M* for poorly-developed crystals of high-silica sericites and mariposite. Neither chemical variation nor environmental control explain the polymorphism.

## INTRODUCTION

Schaller (1950), in interpreting the chemical composition of the high-silica sericites, places them in the muscovite-leucophyllite series and demonstrates that they also contain important amounts of a divalent element, usually magnesium. Varieties placed by Schaller (1950) in this series include phengite, mariposite and alurgite. Other investigators including Whitmore, Berry and Hawley (1946), Hutton (1940) and Webb (1939) also have discussed the relationships of these micas to each other and to other members of the mica family. However, adequate information on the structural properties of these minerals has not been available. Hendricks and Jefferson (1939) note that uniaxial alurgite from St. Marcel, Italy, has crystallized as the 3-layer rhombohedral enantiomorphic hemihedral† polymorph, whereas the so-called alurgite from Cajon Pass, California (Webb, 1939) has the common 2-layer monoclinic (*2M*) muscovite structure. Whitmore, et al. (1946), in their work on the chrome micas, note that mariposite conforms chemically with phengite, which agrees closely with Schaller (1950), and they regard it merely as a chromiferous variety of phengite. However, they had no samples of mariposite suitable for x-ray analysis and state that none are recorded

\* Contribution from the Department of Mineralogy, University of Michigan, No. 189.

† This polymorph has been referred to as rhombohedral, hexagonal and trigonal by various authors. The nomenclature of Smith and Yoder (1954), in which this polymorph is designated as *3T* (Trigonal), has been adopted and will be used in this paper.

by other investigators. Micas of this type commonly have been reported to exist as two phases, a biaxial and a uniaxial or nearly uniaxial phase, which may be intergrown in the same sheet.

In connection with natural mica studies carried on in the Mineralogical Laboratory under Project M978 of the University of Michigan, Engineering Research Institute for the U. S. Army Signal Corp (Heinrich, et al. 1953), and continued subsequently also by the junior author at the Ohio State University, we have obtained a number of high-silica muscovites suitable for  $x$ -ray investigation. Their study reveals that polymorphism is common in high-silica sericites. The Weissenberg method was used wherever feasible, but the flakes of mariposite, of the two alurgites of Meixner (1939), and of the sericites from Amelia, Va., described by Glass (1935) were too minute for Weissenberg techniques, and powder methods were employed. Copper radiation was used throughout.

We wish to thank D. W. Levandowski and C. H. Hewitt for assistance in various details of the investigation and Dr. S. Benedict Levin, Administrator of Project M978 for continuous interest and support. Professor Duncan McConnell has critically read the manuscript. Grateful thanks is given to the following for specimens used: Dr. J. M. Axelrod, Professor C. Frondel, Professor J. Jakob, Dr. H. Meixner, Professor J. Murdoch, Professor A. Pabst, Professor G. Pagliani, Professor R. Parker and Dr. G. Switzer. Dr. H. Yoder kindly aided by supplying information on the identification and differentiation of the *1M* and *1Md* polymorphs.

#### ALURGITE

##### *Alurgite, St. Marcel, Italy*

Both uniaxial and biaxial alurgites from St. Marcel, Italy, the type locality, were studied by means of the Weissenberg method. Some of the flakes contained both uniaxial and biaxial sections. The uniaxial sections have crystallized as the 3-layer trigonal (*3T*) polymorph and the biaxial parts as the common 2-layer monoclinic (*2M*) muscovite polymorph. Penfield (1893) noted that *2E* was as much as  $57^\circ$ ; Larsen and Berman (1934, p. 165) report alurgite, presumably from the same locality, with *2E* as much as  $98^\circ$ . The Penfield (1893) analysis, the only analysis of unquestioned alurgite, apparently was made on material of both uniaxial and biaxial character. Penfield (1893, p. 289) states:

"The largest cleavage plates that have been observed are about 15 mm. in diameter. When examined in convergent polarized light some show a uniaxial others a biaxial interference figure, the double refraction being rather strong and negative. . . . The uniaxial character is undoubtedly the result of twinning, for plates can be found, which in some parts are uniaxial, in others biaxial, and where the plane of the optical axes is in two dif-

ferent positions. Some, moreover, give a confused interference figure, as would be expected from two or more biaxial plates, placed one above the other in twin position. There is no difference in specific gravity between the uniaxial and biaxial plates, they are identical in behavior before the blowpipe and there is every reason for believing that they are the same chemical substance."

It appears possible to simulate a uniaxial interference figure by systematically stacking thin muscovite sheets (Reusch, 1869), but it is structurally impossible to arrange the biaxial portions which have crystallized with the  $2M$  structure in any way so that the  $3T$  structure results.

Although Penfield (1893) states that alurgite is monoclinic, he notes (p. 289):

"When treated with a mixture of strong hydrofluoric and sulphuric acids the biaxial plates show monosymmetric etching figures while those of the uniaxial plates are triangular or hexagonal, similar to those of muscovite and biotite, described by H. Baumhauer."

The  $3T$  structure on St. Marcel alurgite with  $2V=0^\circ$  was first established by Hendricks and Jefferson (1939).

#### *Alurgite, East Tyrol, Austria*

Meixner (1939) reports alurgites from several localities in East Tyrol, Austria. He confirms the presence of uniaxial and biaxial phases in the St. Marcel mica and states that the red mica from Matrei, East Tyrol, has (p. 697), "Genau die gleichen Eigenschaften. . ."

Three specimens of alurgite from this locality were obtained from the Museum of Natural History of Vienna. Our examinations show:

Vienna Number	General Appearance	Optical Characteristics	Structure
J2407	Very minute rose flakes	$2V$ -ca. $35^\circ$	$2M$ muscovite (Weissenberg method)
G5930	Cryptocrystalline, deep red. Associated with Mn-oxides	$2V$ not determinable	$2M$ muscovite (powder method)
G5931	Cryptocrystalline, deep red	$2V$ not determinable	$2M$ muscovite (powder method)

Since chemical analyses of material from this locality are not available, the mineral cannot be classed as alurgite with certainty. The existence of two optical phases whose presence is intimated by Meixner (1939) (see above) was not substantiated.

*Alurgite, India*

Fermor (1909), during a systematic study of the manganese deposits of India, reported four occurrences of red and pink mica, in various associations, which he provisionally regarded as alurgite. A small specimen labeled "Alurgite, Ikabis State, Central India" was received from the Harvard Mineralogical Museum. It bears a general color resemblance to alurgite from St. Marcel; the fragment we have received is biaxial with a large 2V. Weissenberg photographs indicate the  $2M$  muscovite structure. This material can still be regarded as alurgite only provisionally, as no chemical analysis is known.

*"Alurgite," Cajon Pass, California*

The type material of Webb (1939) was reexamined by us by the Weissenberg method and the results are identical with those of Hendricks and Jefferson (1939). This mica is not an alurgite chemically, as has been pointed out by Schaller (1950, also in Webb, 1939) because its silica content is that of a normal muscovite. Since its structure is that of the common  $2M$  muscovite, it must be classed merely as a ferrian muscovite. Dr. Webb (personal communication) states that he is no longer convinced that his material is true alurgite.

*"Alurgite," Ultevis, Sweden*

The "alurgite" described by Ödman (1950) contains only 43.67 per cent  $\text{SiO}_2$  and 4.36  $\text{Fe}_2\text{O}_3$  and is chemically, therefore, a ferrian muscovite and not "alurgite." Weissenberg photographs of flakes of this mica show that it has the common  $2M$  muscovite structure.

## MARIPOSITE

No mariposite suitable for single-crystal work could be obtained and the powder method was therefore used for structure identification. Two specimens of fine grained mariposite, one from Carson Hill, Calaveras County, California, and the other from San Francisquito Canyon, Los Angeles County, California, the latter described by Murdoch and Webb (1938), have been studied and found to have the  $2M$  muscovite structure. Unfortunately, the Carson Hill material is so fine grained and has such poor crystal development that it is impossible to determine the optical properties with certainty. In the case of the San Francisquito material, Murdoch and Webb (1938) state that the mariposite is found in flakes 10–12 mm. in diameter, but these "flakes" are actually aggregates of fine grained material. A few small areas of several of these "flakes" are relatively coarsely crystalline, and from these biaxial interference figures were obtained. 2V was estimated to be as large as  $35^\circ$ . Since no analysis

for  $\text{SiO}_2$  was made, this mica could be a chromian muscovite (fuchite with normal  $\text{SiO}_2$ , rather than a chromian phengite (mariposite) with high  $\text{SiO}_2$ ).

TABLE 1. X-RAY POWDER DATA ON MARIPOSITES.  
(WITH FILTERED Cu RADIATION)

<i>1M</i> polymorph				<i>2M</i> polymorph			
Mother Lode fault zone Mariposa County, California				Carson Hill, Calaveras County, California			
<i>d</i> (Å)	<i>I</i>	<i>d</i> (Å)	<i>I</i>	<i>d</i> (Å)	<i>I</i>	<i>d</i> (Å)	<i>I</i>
10.0	S	2.13	Wd	10.0	S	2.48	MW
4.99	M	2.00	Md	4.99	M	2.39	M
4.48	S	1.72	VW	4.49	S	2.25	W
3.67	M	1.66	Wd	4.32	VW	2.20	W
3.35	S	1.51	S	4.11	VW	2.13	M
3.08	M	1.38	VW	3.88	M	1.99	S
2.84	VVW	1.35	W	3.73	M	1.72	VVW
2.57	S	1.30	W	3.49	M	1.65	M
2.39	M	1.25	W	3.33	S	1.60	VVW
2.26	W			3.20	M	1.56	VVW
				2.99	M	1.50	MS
				2.86	M	1.42	VVW
				2.78	MW	1.35	MW
				2.57	S	1.34	W
						1.30	MW
						1.25	W

Specimens of the mariposite with small  $2V$  described by Knopf (1929) from the Mother Lode area of California as well as the mariposite with  $2V < 10^\circ$  from Hoggar, Algeria, described by Sandréa (1950) could not be obtained. However, a specimen from the Rawhide Mine, California (Harvard Museum number 86911) noted by Whitmore, et al. (1946, p. 14) to have a  $2V$  of  $12^\circ$  was secured. Powder  $x$ -ray photographs of this material indicate the 1-layer monoclinic (*1M*) mica polymorph.

Another specimen of mariposite received from Professor A. Pabst has also been found to have the *1M* mica structure. This previously undescribed specimen was collected from the "Mother Lode fault zone north of State Highway 140, northeast corner of Indian Gulch quadrangle, Mariposa County, California." It is typical of all mariposite specimens seen and is intimately associated with quartz.  $2V$  could be determined on only one flake and was noted to be approximately  $10^\circ$ . Although careful selection of other mariposite flakes under a microscope had usually yielded pure material (no extraneous  $x$ -ray powder lines), the

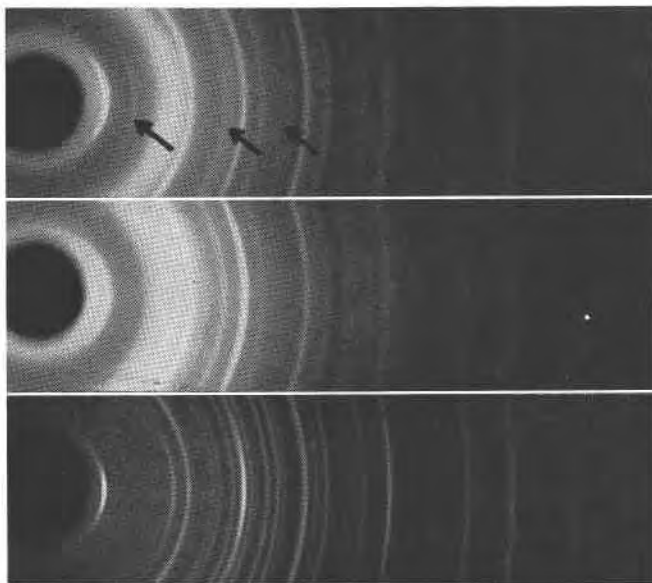


FIG. 1. *Top*: Mariposite from Mother Lode fault zone, Indian Gulch quadrangle, Mariposa County, California, showing *1M* structure contaminated with lines of a kaolinite type mineral (arrows). *Middle*: Same material as above heated for 3/4 hour at 575° C. in air showing diffraction lines only of the *1M* mica polymorph. *Bottom*: Mariposite, Los Angeles County, California described by Murdoch and Webb (1938) showing *2M* structure. This pattern is essentially identical with that of *2M* mariposite from Carson Hill, Calaveras County, California (Table 1).

(All photographs with filtered copper radiation.)

Indian Gulch mariposite showed contamination by a kaolinite-type mineral, with characteristic diffraction lines at 7.1, 3.55, etc. After the specimen was heated to 575° C. for 3/4 of an hour, the lines attributed to the kaolinitic mineral disappeared. Figure 1 illustrates the powder patterns of the *1M* structure obtained from this mariposite both before (top) and after heating (middle). Table 1 lists the interplanar spacing of a *1M* mariposite.

#### PHENGITE

*Phengite, Fontane, Germanasca Valley, Italy*

The phengite analyzed and described by Pagliani (1937) is reported to have a *2V* of about 11°. The *2V* of the type material we received is larger than 11°, ranging generally from 18° to 35° (estimated). Weissenberg photographs of sections with *2V* near 35° show the *2M* muscovite structure, but photographs of the sections with the smaller *2V* have patterns of the *2M* form combined with what appears to be the *3T* poly-

morph. It is probable that patterns of the phengite with  $2V = 11^\circ$  might be those of the  $3T$  polymorph alone.

Specimens of a mica called muscovite by Jakob (1929A, his number 43) have been studied. This mica, from Passo di Ganano, Soazza, Val Mesocco, is uniaxial, and Weissenberg photographs show that it has crystallized as the  $3T$  structure. It is a high-silica muscovite ( $\text{SiO}_2 = 49.01$  per cent) and has the required, relatively large, content of a divalent element,  $\text{MgO} = 3.91$  per cent. This mica probably was called muscovite by Jakob (1929A), rather than phengite, because of its occurrence and paragenesis, for the term phengite apparently has been used by some investigators for very fine grained high-silica muscovites of secondary origin. Although this mica is predominantly uniaxial, several small basal areas in a few flakes show birefringence and have a moderate  $2V$ . One such isolated biaxial part proved to have the  $2M$  muscovite structure.

#### *Phengites with the $2M$ muscovite structure*

Jakob has analyzed five other high-silica muscovites all of which we have examined and found to have the normal  $2M$  muscovite structure. Data on these micas are as follows:

Reference	Name	$\text{SiO}_2$	$\text{MgO}$	$\text{FeO}$	$\text{Fe}_2\text{O}_3$
Jakob (1925) No. 18	muscovite	50.79	2.80	1.34	2.94
Jakob (1929A) No. 44	phengite	50.64	4.15	1.01	2.97
Jakob (1929A) No. 45	sericite	48.80	5.74	0.00	5.86
Jakob (1929A) No. 46	sericite	50.20	3.82	0.00	9.62
Jakob (1929B) No. 54	muscovite	50.04	3.64	0.85	2.44

Nos. 18 and 54 have normal  $2V$ s; the others are too fine grained for  $2V$  determination.

#### *Phengite from Adula Mountains, Switzerland*

The mica from Mt. Mucrone, Switzerland, described by Kunitz (1924) is uniaxial and is called phengite ( $\text{SiO}_2 = 50.45$  per cent) by him. Specimens of this material could not be secured for  $x$ -ray studies.

Axelrod and Grimaldi (1949, p. 560) note, "Carl Schmidt found, in a gneiss from the Adula Mountains, Switzerland, a green pleochroic muscovite that was uniaxial. It became biaxial on heating and on cooling became uniaxial again."

Analyses of what appears to be similar uniaxial material, and also of an associated biaxial mica ( $2E = 52^\circ$ ) from the Adula Mountains, also collected by Schmidt, have been reported by Wülfing (1886). Analyses of both types indicate slightly high silica (47.69 and 47.72 per cent), high  $\text{MgO}$  (2.72 and 2.30 per cent) and high total iron (4.90 and 8.31 per

cent), values which are essentially characteristic of phengite. The most striking difference in the two analyses is the higher ferrous iron content of the biaxial part, i.e. 6.55 per cent FeO as compared with 3.88 per cent for the uniaxial material.

A sample supposedly of Wülfing's (1886) uniaxial phengite was obtained from the Museum of Natural History of Vienna (No. G3399). Optical examination of the sample reveals the presence of two phases: a uniaxial type and a normal biaxial muscovite, which are otherwise markedly similar. Weissenberg photographs of the uniaxial variety show it to possess the  $3T$  structure, whereas the mica with the normal  $2V$  has crystallized as the  $2M$  muscovite type. In view of this admixture of the two varieties in material supposed to be homogeneous, it is doubtful that the chemical differences reported by Wülfing (1886) are significant.

#### *Sericites from Amelia, Virginia*

Glass (1935) has described five sericites from Amelia, Virginia. Powders of the analyzed material were secured from the U. S. Geological Survey, and powder  $x$ -ray patterns were obtained.

Varieties 1 and 2 have slightly high silica contents (48.06 and 47.22 per cent) as well as MgO contents (1.39 and 1.25 per cent) and probably should be considered related to the above mentioned phengites.  $2V$  is reported from  $70$ – $80^\circ$  for variety 1 and  $70$ – $75^\circ$  for variety 2.  $X$ -ray studies on these varieties indicate the 1-layer monoclinic mica structure. However the  $(112)$  and  $(11\bar{2})$  reflections, which correspond with approximately  $d=3.08$  Å and  $3.67$  Å respectively, are of low intensity. On the basis of the experiences of Yoder and Eugster (1954, p. 173) and Levinson (1955) the low intensity of these reflections is probably caused by a random stacking of the mica layers. Yoder and Eugster (1954) show several degrees of ordering between a completely disordered ( $IMd$ ) and an ordered one-layer ( $IM$ ) phlogopite. The degree of ordering of these sericites is not easily determined and they may approach closely the  $IMd$  type.

Varieties 3 and 4 have silica contents that are essentially normal (46.81 and 46.80 per cent), as are their MgO contents (0.62 and 0.56 per cent).  $2V$  is reported as  $30$ – $40^\circ$  and variable for both types.  $X$ -ray powder patterns of both varieties are identical. Although they contain characteristic mica lines it was not possible to determine the polymorph with certainty.

Variety 5 is a true phengite or high-silica sericite with 49.16 per cent  $SiO_2$  and comparable high MgO (2.22 per cent). Glass (1935) reports  $2V$  for this specimen as  $0$ – $3^\circ$ . An  $x$ -ray powder pattern of this mica shows that it has crystallized with the  $2M$  structure. The optic angle of this mica, as well as those of the other micas could not be checked because of the extremely fine grained nature of the powdered sample.



## DISCUSSION

It has generally been assumed from the work of Hendricks and Jefferson (1939) that muscovite crystallizes with essentially one structure, the  $2M$ . However, these muscovites appear to be predominantly, if not entirely, of pegmatitic origin. The mica from Sultan Basin, Washington, described by Axelrod and Grimaldi (1949), which is now known to be  $3T$  (Smith and Yoder (1954)), and has been considered anomalous by some investigators, is not of pegmatitic origin. The results of our investigation further indicate that the  $2M$  polymorph is not unique for muscovite-type micas and especially for the high-silica types of hydrothermal and metamorphic origins. Similar results, in which the  $3T$ ,  $2M$ ,  $1M$  and  $1Md$  polymorph have been found, are described by Levinson (1955) among the hydrous micas. Also Heinrich and Levinson (1955) have determined the structures of some roscoelites and a barium-muscovite to be  $1M$ . Clearly the  $2M$  structure can not be considered representative or unique for muscovite-type micas as a whole.

The data presented in this paper show some definite relationships between crystal structure,  $2V$  and crystal development. In the case of the phengites and alurgites that are sufficiently well developed for Weissenberg study, the following relationships have been observed: if  $2V$  is  $0^\circ$  or small (less than approximately  $15^\circ$ ), the structure is  $3T$ ; if the mica is distinctly biaxial with a moderate or large  $2V$ , the structure is  $2M$ . In the case of the very fine grained, poorly developed, high-silica sericites and mariposite, which required study by the powder method, the following characteristics have been observed: if  $2V$  is moderate or large, the structure is  $2M$ ; if  $2V$  is  $0^\circ$  or small, the  $1M$  (or  $1Md$ ) structure obtains. The  $2V$  of the high-silica sericites described by Glass (1935), which are not in accord with the above generalizations, have not been redetermined by us, and therefore, are not considered in these conclusions. Therefore the high-silica muscovites with small  $2V$  are worthy of further study, because they are the type in which to date the  $1M$  and  $3T$  polymorphs have been found. In addition to the examples discussed, several others of this type have been reported, specimens of which we have been unable to obtain. These are briefly noted below.

Scheerer (1862, p. 63) described two uniaxial micas from a gneiss near Freiberg, Germany, which are high in silica and are considered to be phengite.

Buryanova (1940) reports a yellowish-green mica with  $2V=8^\circ$  from a granitic pegmatite of the Korosten pluton in Volhynia. It is associated with albitized orthoclase, lamellar albite, fluorite and a markedly biaxial mica.

Clark and Hunt (1915) concluded that the mica in a dolomitic marble

TABLE 2. DATA ON ALURGITES, MARIPOSITES AND PHENGITES

Name	Locality	Optic Angle	Structure	Reference	Occurrence and Origin
Alurgite	St. Marcel, Italy	2V=0°	3T	Penfield (1893)	Metamorphic manganese deposits
Alurgite	St. Marcel, Italy	2V=ca. 35°	2M	Penfield (1893)	Metamorphic manganese deposits
Alurgite	East Tyrol, Austria	2V=ca. 35°	2M	Meixner (1939)	Metamorphic manganese deposits
Alurgite	East Tyrol, Austria	2V=?	2M	Meixner (1939)	Metamorphic manganese deposits
Mariposite	Calaveras Co., Calif.	2V=?	2M	This paper	Hydrothermal; associated with ankerite, quartz, sulfides and gold veins.
Mariposite	Rawhide Mine, Calif.	2V=12°*	1M	Whitmore, et al. (1946)	
Mariposite	Mariposa Co., Calif.	2V=ca. 10°	1M	From A. Pabst	In talc schist
Mariposite	Los Angeles Co., Calif.	2V=moderate	2M	Murdoch and Webb (1938)	
Phengite	Fontane, Italy	2V=ca. 35°	2M	Pagliani (1937)	Mica schist overlying talc lens
Phengite	Fontane, Italy	2V=ca. 18°	2M+3T?	Pagliani (1937)	Mica schist overlying talc lens
Phengite	Adula Mts., Switz.	2V=0°	3T	Wülfing (1886)	Gneiss
Phengite	Adula Mts., Switz.	2V=moderate	2M	Wülfing (1886)	Gneiss
Phengite	Val Mesocco, Switz.	2V=0°	3T	Jakob (1929A)	Alpine cleft vein in eclogite
Phengite	Val Mesocco, Switz.	2V=moderate	2M	Jakob (1929A)	Alpine cleft vein in eclogite
Sericite	Amelia, Virginia	2V=70-80°*	1M	Glass (1935) var. 1	Secondary, alteration of feldspars and topaz
Sericite	Amelia, Virginia	2V=70-75°*	1M	Glass (1935) var. 2	
Sericite	Amelia, Virginia	2V=0-3°*	2M	Glass (1935) var. 5	

W = Structure determined by Weissenberg method.

P = Structure determined by powder method.

\* = Indicates 2V obtained from literature and not redetermined.

2V=0° may indicate a very small 2V.

Moderate = distinctly biaxial with 2V approximately 30-40°.

from Cockeysville, Maryland, was a muscovite, even though it has the optical properties of a phlogopite. Their conclusion was based on a partial analysis of the rock which showed a discrepancy in the  $\text{Al}_2\text{O}_3:\text{SiO}_2$  ratio for phlogopite. A specimen of this mica has been examined by the Weissenberg method and the structure determined to be  $1M$  with intensities identical with  $1M$  phlogopites. It is, therefore, a phlogopite and not a muscovite with a small  $2V$ .

Shibata (1952*A*, p. 135) notes, with respect to a mica from the Bunsen Mine, Korea: "White mica associated with pink lepidolite is uniaxial negative under the microscope and is considered as phengite." An analysis of this material is also presented (Shibata 1952*B*, p. 150). Shibata (1952*B*) also describes a "lithium phengite" from the Uruchin Mine, Korea and states (p. 153): ". . . is optically uniaxial and has high contents of iron and magnesium. These characteristics coincides (sic) with those of phengite and this variety is to be called for 'Li-phengite' (sic) by its high content of lithium."

The cause of the polymorphic variations is not known. Several possibilities have been considered, but the results are inconclusive. For example, no systematic differences in composition are known to distinguish the several structural types. Actually there is no certainty as to whether the few available analyses were carried out on completely uniaxial ( $3T$  or  $1M$ ) or biaxial ( $2M$ ) material, except possibly those of Wülfing (1886). From the small-scale nature of the optical variation, material of both types may have been involved in each analysis. The phengite of Pagliani (1937) is a good example; the literature indicates that the analysis was performed on material with a  $2V$  of about  $11^\circ$ , whereas the material sent by Professor Pagliani has a predominant biaxial phase. It does not seem likely, however, that the control of the polymorphism can be ascribed entirely to compositional variations. High-silica sericites of apparently the same composition may or may not crystallize as several polymorphs. If the high silica content exercises any control on the structure, it seems to be a permissive rather than a requisite control.

The environmental factors are even more difficult to evaluate. Table 2 lists most of the high-silica sericites studied together with  $2V$ , structure, their mode of occurrence, and available information regarding their origin. Although the data are incomplete, it is striking that none of these micas formed by crystallization from a granitic or pegmatitic magma. They are either of hydrothermal origin or occur in metamorphic rocks, in which their origin is unspecified. These relations suggest that, if the polymorphism is controlled in any way by or related in any manner to the high silica or associated chemical content, an unknown physical factor, furnished by a hydrothermal or metamorphic environment, also

must be active in crystallization. Any such postulated environmental control must be exceedingly delicate in order to account for the small-scale intergrowths of the two polymorphs in the same sheet, as in the case of alurgite. In order to solve this problem, more muscovites must be studied, and new analyses made on material of uniaxial character must be compared to analyses of material that is entirely biaxial.

NOTE ADDED IN PRESS:

M. Nakahira (*Acta Crystallographica*, **7**, p. 684, 1954) has observed "... a two-layered (muscovite-type) and a three-layered (pseudo-trigonal) structure, or an intermediate type of these two" in sericites from the Unnan Mine, Shimane Prefecture, Japan. No optical or geologic data are given in his abstract.

S. Kilpady and A. S. Dave (*Proc. Indian Acad. Sci.*, **39**, pp. 53-63, 1954) have described what they believe to be an alurgite from a pegmatite at the Sitasaongi Mine, Bhandara District, India. Because of its normal SiO<sub>2</sub> content (45.6 per cent) and high Fe<sub>2</sub>O<sub>3</sub> content (5.8 per cent) this mica should be called a ferrian muscovite. We have determined the polymorph of a specimen of this crimson mica received from Dr. Kilpady to be *2M* and thus it is structurally a normal muscovite.

REFERENCES

- AXELROD, J. M., AND GRIMALDI, F. S. (1949), Muscovite with small optic axial angle: *Am. Mineral.*, **34**, 559-572.
- BURYANOVA, E. Z. (1940), An account of the mineralogy of granite pegmatites from the Korosten plutone massif in Volhynia and of a study of their iron biotites: *Mem. Soc. Russe. Min.*, **69**(4), 519-540.
- CLARK, R. W., AND HUNT, W. F. (1915). Ungewöhnliche optische Eigenschaften des Muscovits in dem Mar Villa-Marmor von Cockeysville, Maryland: *Centralblatt Min., Geol., Pal.*, **1915**, 666-668.
- FERMOR, L. L. (1909), The manganese-ore deposits of India: *Mem. Geol. Surv. India*, **37**, 1-1294.
- GLASS, J. J. (1935), The pegmatite minerals from near Amelia, Virginia: *Am. Mineral.*, **20**, 741-768.
- HEINRICH, E. WM., LEVINSON, A. A., LEVANDOWSKI, D. W., AND HEWITT, C. H. (1953), Studies in the natural history of micas; *Univ. Mich., Eng. Res. Inst. Final Rpt., Proj. M978*.
- AND LEVINSON, A. A. (1955), Studies in the mica group; X-ray data on roscoelite and barium-muscovite: *Am. Jour. Sci.*, **253**, 39-43.
- HENDRICKS, S. B., AND JEFFERSON, M. E. (1939), Polymorphism of the micas: *Am. Mineral.*, **24**, 729-771.
- HUTTON, C. O. (1940), Optical properties and chemical composition of two micas from Westland, South Island, New Zealand: *New Zealand Jour. Sci. Tech., Sec. B*, **21**, 330-331.
- JAKOB, J. (1925), Beiträge zur chemischen Konstitution der Glimmer. II Mitteilung. Die Muskovite der Pegmatite. I. Teil. *Zeit. Krist.*, **62**, 443-453.

- (1929A), Beiträge zur chemischen Konstitution der Glimmer. VI Mitteilung. Die nicht pegmatitischen Muskovite. I Teil: *Zeit. Krist.*, **69**, 511–515.
- (1929B), Beiträge zur chemischen Konstitution der Glimmer. VII Mitteilung: Die Muskovite der Pegmatite. III Teil: *Zeit. Krist.*, **70**, 493–496.
- KNOPF, A. (1929), The Mother Lode system of California: *U. S. Geol. Surv., Prof. Paper* **157**, 38.
- KUNITZ, W. (1924), Die Beziehungen zwischen der chemischen Zusammensetzung und den physikalisch-optischen Eigenschaften innerhalb der Glimmergruppe: *Neues Jahrbuch Min., Beilage-Band*, **50**, 365–413.
- LARSEN, E. S., AND BERMAN H. (1934), The Microscopic Determination of the Nonopaque Minerals: *U. S. Geol. Surv., Bull.* **848**.
- LEVINSON, A. A. (1955), Studies in the mica group; Polymorphism among illites and hydrous micas: *Am. Mineral.*, **40**, 41–49 (1955).
- MEIXNER, H., (1939), Alurgit und seine Vorkommen: Beziehungen zu Fuchsit und Marioposit: *Ann. naturhist. Museums Wien*, **50**, 694–703.
- MURDOCH, J., AND WEBB, R. W., (1938), Notes on some minerals from southern California: *Am. Mineral.*, **23**, 349–355.
- ÖDMAN, O. H. (1950), Manganese mineralization in the Ultevis District, Jokkmokk, North Sweden: Part 2, Mineralogical Notes: *Sveriges Geol. Undersök. Ser. C., Årsbok* **44**, No. 2.
- PAGLIANI, G. (1937), Sur una mica della miniera di talco delle Fontane (Valle della Germanasca): *Atti. Soc. Ital. Sci. Nat. Mus. Civ. Milano*, **76**, 13–16.
- PENFIELD, S. L. (1893), On some minerals from the manganese mines of St. Marcel, in Piedmont, Italy: *Am. Jour. Sci.*, **46**, 288–295.
- RUESCH, E. (1869), Untersuchung über Glimmercombinationen: *Pogg. Ann. Phys. Chem.*, **138**, 628–638.
- SANDRÉA, A. (1950), Sur un schiste chromifère du Hoggar: *Bull. Soc. Franc. Min.*, **73**, 446–453.
- SCHALLER, W. T. (1950), An interpretation of the composition of high-silica sericites: *Mineral., Mag.*, **29**, 405–415.
- SCHEEERER, T. (1862), Die Gneuse des sächsischen Erzgebirges und verwandte Gesteine, nach ihrer chemischen Constitution und geologischen Bedeutung: *Zeit. Deutsch. Geol. Gesells.*, **14**, 23–150.
- SHIBATA, H. (1925A), Mineralizations in granite-pegmatites in Japan and Korea. Part II: *Tokyo Univ. Lit., Sci., Sci. Rpts., Sec. C*, **2**, (10), 107–144.
- (1925B), Spodumene and amblygonite from the Bunsen Mine, and other localities in Korea: *Tokyo Univ. Lit. Sci., Sci. Rpts., Sec. C*, **2**, (11), 145–153.
- SMITH, J. V., AND YODER, H. S. (1954), Theoretical and x-ray study of the mica polymorphs (abs): *Am. Mineral.*, **39**, 343–344.
- WEBB, R. W. (1939), Investigation of a new occurrence of alurgite from California: *Am. Mineral.*, **24**, 123–129.
- WHITMORE, D. R. E., BERRY, L. G., AND HAWLEY, J. E. (1946), Chrome micas: *Am. Mineral.*, **31**, 1–21.
- WÜLFING, E. A. (1886), Untersuchung zweier Glimmer aus den Gneissen des Rheinwaldhorn-Massivs, Graubünden: *Ber. Deutsch. Chem. Gesells.*, **19**, 2433–2438.
- YODER, H. S., AND EUGSTER, H. P. (1954), Phlogopite synthesis and stability range: *Geochimica et Cosmochimica Acta*, **6**, 157–185.