

## IRON-RICH MUSCOVITIC MICA FROM THE GRANDFATHER MOUNTAIN AREA, NORTH CAROLINA\*

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### ABSTRACT

The metamorphic arkoses and arkosic quartzites in the Grandfather Mountain area, North Carolina, contain green micas that have high indices of refraction with the  $\beta$  index ranging from 1.603 to 1.619. Detailed study of mica having the highest indices of refraction showed that it is dioctahedral in character, falling between muscovite and phengite in the trisilicic-tetrasilicic dioctahedral potassium mica series, with considerable proxying of  $\text{Fe}^{+3}$  for octahedral Al. The green color and high indices of refraction are attributed to the high iron content and to the presence of both  $\text{Fe}^{+3}$  and  $\text{Fe}^{+2}$  (8.11 per cent  $\text{Fe}_2\text{O}_3$  and 2.55 per cent FeO).

### INTRODUCTION AND REGIONAL GEOLOGY

In the course of geologic mapping in the Grandfather Mountain area, North Carolina, (one of us (B. B.)) observed rocks containing a fine-grained green mica. The green aspect of the rocks strongly suggests the presence of chlorite in addition to mica. However, thin section study showed that no chlorite is present; the green color of the rocks is due entirely to the mica. Preliminary optical study showed that the mica is muscovitic in type but has much higher indices of refraction than usual in such micas. The high indices of refraction, and the color, incited our interest in making a more detailed study of this mica.

The Grandfather Mountain area is on the eastern edge of the Blue Ridge province 56 miles northeast of Asheville, N. C. The area is underlain by early Precambrian basement rocks and late Precambrian and early Cambrian sedimentary and igneous rocks. These rocks are surrounded by early Precambrian schists, amphibolites, gneisses, and granitic rocks. Keith (1903) interpreted the structure of this area as a complex synclinal downfold bordered by opposing thrusts. A. I. Jonas and G. W. Stose (Geologic map of the U. S., 1932) first recognized this structure as a window, and the present workers agree with that interpretation. For a summary of the regional geology see King (1955).

Retrogressive metamorphism of the basement rocks has produced a cataclastic foliation and recrystallization with development of new biotite and albite in rocks of appropriate composition both within the window and in the upper plate adjacent to the window. Progressive metamorphism in the late Precambrian and early Cambrian rocks was of the same grade.

In the window two sequences of sedimentary rocks are recognized:

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an autochthonous sequence unconformably overlying the basement rocks and an allochthonous sequence in thrust contact with members of the allochthonous sequence and the basement rocks (Reed and Bryant, 1958). The upper sequence consists of arkosic quartzite, phyllite, and quartzite underlying dolomite, which appears to be equivalent to the Shady dolomite of the Valley and Ridge province. The lower sequence consists of an interbedded and interlensing sequence of meta-arkose, calcareous biotite phyllite, phyllite, metasiltstone, metagraywacke, and greenschist.

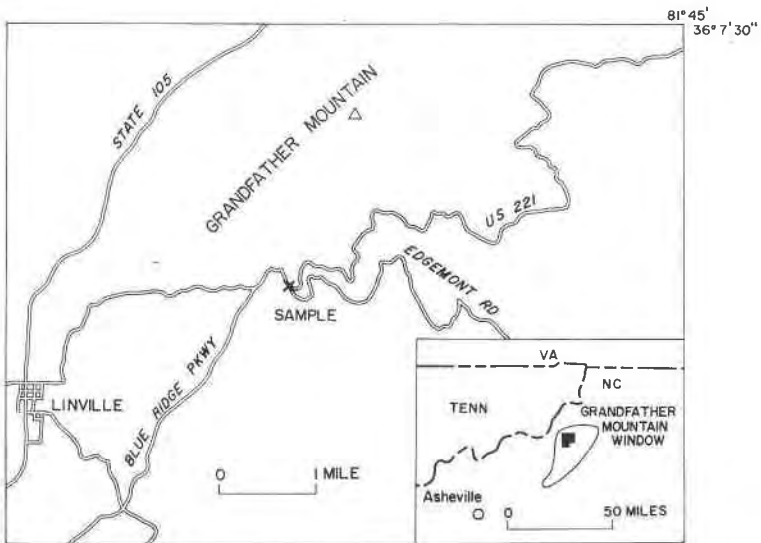


FIG. 1. Location of sample.

### THE GREEN MICA

Most of the metamorphosed arkoses and arkosic quartzites in both sequences contain green muscovitic mica; the rocks range from light greenish-gray to green. The  $\beta$  index of the mica from some of the greener rocks ranges from 1.603 in some specimens to 1.619 in others. A sample containing mica of the highest index of refraction found was chosen for further study.

The sample selected was collected from a roadcut on U. S. Highway 221 about 1,000 feet southeast of the junction with the Edgemont road on the southeast side of Grandfather Mountain one-half mile east of the crest of the Blue Ridge (Fig. 1). This specimen is a green micaceous arkosic quartzite from the lowest member of the autochthonous sequence.

The rock displays cleavage cutting bedding at an angle of  $15^\circ$ . Green mica is concentrated along the cleavage planes, which are as much as 2 mm. apart in the coarser beds. Quartz and microcline clasts up to 2 mm. and plagioclase clasts up to 0.7 mm. in diameter occur in a matrix of recrystallized quartz which has an average grain size of 0.1 mm. Feldspar at least as small as 0.1 mm. retains its clastic outline, whereas quartz as large as 0.3 mm. is recrystallized and participates in mosaic texture. The mica is well aligned parallel to the cleavage and from 0.02 to 0.5 mm. long. It includes aggregates of sphene and leucoxene.

#### Mode of sample

quartz.....	45.8
potassium feldspar.....	14.5
plagioclase.....	8.1
green mica.....	29.2
sphene and leucoxene.....	1.7
epidote.....	.3
apatite.....	.3
zircon.....	tr.

#### Optical properties

The green mica has the following optical properties:

$\alpha = 1.580 \pm 0.001$ (colorless)	$\gamma - \alpha = .043 \pm .01$
$\beta = 1.6195 \pm .0005$ (light green)	optic sign = negative
$\gamma = 1.6230 \pm .0005$ (light green)	$2V = 35^\circ \pm 3^\circ$

The indices were determined with Na light in oils graduated in two thousandths. The  $\alpha$  index was determined on the spindle stage (Wilcox, 1959) and the optic axial angle by Mallard's method.

#### SEPARATORY PROCEDURE

The sample was crushed and divided into two fractions: 100-200 mesh and 200-400 mesh. The mica was separated by a process of repeated treatment in a Bendix ultrasonic transducer and separation in a Frantz isodynamic separator. Each fraction was treated for two 20-minute intervals in the ultrasonic transducer and run through the isodynamic separator with  $25^\circ$  forward tilt and  $15^\circ$  side tilt at 1.0 amperes. The magnetic fraction from this run was treated again in the transducer and run through the separator at 0.9 amperes. This process was repeated, at each run decreasing the amperage by about 0.1 ampere. The treatment in the ultrasonic transducer shredded the mica flakes and freed minute inclusions of sphene, quartz, and feldspar which went into suspension and were decanted.

An amperage of 0.55 separated the green mica from the less magnetic

constituents. This fraction was run again at 0.45 amperes to remove magnetite, yielding a concentrate of about 99% mica in the 200–400 mesh fraction, and about 98% in the 100–200 mesh fraction. The impurities were very fine grained, but were probably chiefly sphene and leucoxene.

#### X-RAY ANALYSIS

Both  $x$ -ray powder photographs and diffractometer patterns were used in the examination of the green mica. Two different diffractometers were used, operated at the following settings:

Radiation: Cu/Ni	Scale factor 4
KVP—40; MA—20	Multiplier 1
Scanning speed $\frac{1}{8}^\circ$ per minute	Time constant 4
Low $2\theta$ cutoff	Sample length 20 mm.
Divergence slit $1^\circ$	
Receiving slit 0.003 inch	
Scatter slit $1^\circ$	

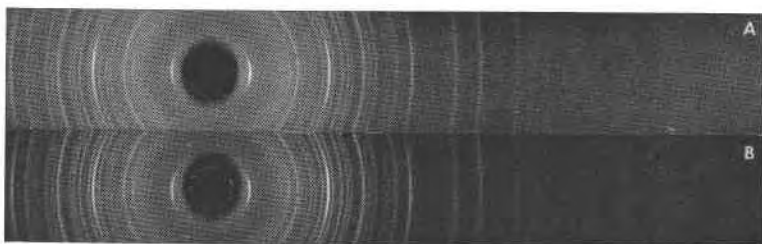


FIG. 2. X-ray powder photographs of: (A) Green mica from the Grandfather Mountain area, N. C., and (B) 2M Muscovite, Ontario 114.59 mm camera,  $\text{CuK}\alpha$ , Ni filtered radiation.

The powder photographs were made of both relatively coarse and of finely ground material, with 114.59 mm. diameter cameras using exposures of about 12 hours.

The similarity between the green mica and 2M muscovite is shown in Fig. 2. Some slight differences may be noticed between the patterns, in particular the spacing of the 060 reflection. Other differences became apparent when an attempt was made to index the pattern by comparison with the muscovities listed in the ASTM  $x$ -ray diffraction data card file (1958). It was found necessary to calculate provisional unit-cell parameters using assumed indices. This unit cell is confirmed by the good agreement of the observed and calculated spacings shown in Table 1.

The  $a_0$  and  $b_0$  dimensions are larger than normal for muscovite, whereas the  $c_0$  dimension is slightly smaller:

TABLE 1. X-RAY DATA FOR GREEN MICA FROM GRANDFATHER MOUNTAIN AREA, NORTH CAROLINA

$a_0$ 5.249Å				$b_0$ 9.064Å				$c_0$ 19.991Å				$\beta = 95^\circ 45'$			
<i>hkl</i>	<i>d</i> (calc.)	<i>d</i> (obs.)	I/I <sub>1</sub>	<i>hkl</i>	<i>d</i> (calc.)	<i>d</i> (obs.)	I/I <sub>1</sub>	<i>hkl</i>	<i>d</i> (calc.)	<i>d</i> (obs.)	I/I <sub>1</sub>	<i>hkl</i>	<i>d</i> (calc.)	<i>d</i> (obs.)	I/I <sub>1</sub>
002	9.945	9.958	100 <sup>1</sup>	12·11	1.6440	1.6442	5								
004	4.972	4.972	19 <sup>1</sup>	31 $\bar{5}$	1.6298	1.6276	8								
110	4.525	4.525	50	228	1.6054	1.6047	14								
111	4.497	4.498	73	049	1.5822	1.5818	5								
021	4.419	4.421	18	155	1.5546	1.5608	13								
111	4.331	4.326	20	13·10	1.5462	1.5456	5								
022	4.124	4.130	15	13·11	1.5235	1.5239	20								
112	3.990	3.992	10	060	1.5108										
113	3.898	3.897	51	247	1.5105	1.5107	36								
023	3.742	3.748	46	331	1.4952										
113	3.595	3.590	8	061	1.4937	1.4939	2								
114	3.501	3.501	75	335	1.4527	1.4515	15								
024	3.350	3.349	85	158	1.4326	1.4316	8								
006	3.315	3.316	100 <sup>1</sup>	00·14	1.4206	1.4198	12 <sup>1</sup>								
114	3.211	3.208	94	336	1.4201										
115	3.126	3.120	14	11·13	1.4126	1.4112	10								
025	2.990	2.993	100	065	1.4123										
115	2.867	2.864	79	158	1.3892	1.3882	5								
116	2.793	2.792	64	066	1.3747	1.3757	8								
200	2.611			13·13	1.3504	1.3506	44								
131	2.610	2.612	29	04·12	1.3378	1.3376	31								
131	2.576	2.579	90	11·14	1.3230										
117	2.506			22·13	1.3217	1.3223	15								
132	2.499	2.504	20	400	1.3055										
008	2.486	2.486	12 <sup>1</sup>	20·14	1.3040	1.3042	21								
204	2.413			13·13	1.2926	1.2931	7								
027	2.407	2.409	32	04·13	1.2680	1.2689	8								
133	2.392	2.394	36	170	1.2569	1.2568	9								
134	2.268			352	1.2571										
040	2.266	2.266	12	351	1.2475	1.2485	5								
135	2.237	2.242	9	00·16	1.2431	1.2431	9 <sup>1</sup>								
204	2.222	2.217	7	173	1.2295	1.2289	4								
206	2.159	2.158	18	353	1.2177	1.2174	10								
135	2.137	2.139	36	357	1.1804	1.1807	3								
223	2.087	2.081	4	22·14	1.1587										
044	2.062	2.060	3	11·17	1.1573	1.1580	8								
225	2.044	2.043	5	24·14	1.1302	1.1294	8								
243	1.9897			357	1.1190										
00·10	1.9889	1.9897 <sup>2</sup>	80 <sup>1</sup>	31·12	1.1189	1.1194	5								
137	1.9742	1.9741	55	083	1.1169	1.1175	4								
226	1.9491	1.9517	21	22·17	1.0781	1.0776	3								
11·10	1.8819	1.8830	8	35·11	1.0681	1.0677	2								
138	1.8488	1.8471	3	20·18	1.0563	1.0566	4								
02·10	1.8213	1.8195	5	13·17											
228	1.7506	1.7480	10	429	1.0485	1.0483	14								
11·11	1.7316			33·15	1.0417										
139	1.7313	1.7314	13	511	1.0416	1.0416	3								
312	1.7131			282	1.0296										
150	1.7127	1.7134	13	374	1.0294	1.0296	5								
227	1.6995	1.6998	8	373	1.0172	1.0173	2								
20·10	1.6646	1.6631	30	33·16	1.0029	1.0028	2								
312	1.6577	1.6578	10 <sup>1</sup>	11·20	.98944	.98961	10								
00·12	1.6574														
139	1.6477	1.6485	64												

<sup>1</sup> The strongest 00*l* and *hkl* lines were each assigned an intensity of 100 because preferred orientation could not be eliminated in the specimens used and the true intensity relationships between 00*l* and *hkl* reflections could not be determined. The intensities of all of the 00*l* reflections are relative to the 002.

<sup>2</sup>  $\lambda = 1.54050\text{\AA}$  for this and all smaller spacings. For large spacings  $\lambda = 1.5418\text{\AA}$ .

	$a_0$	$b_0$	$c_0$	$\beta$
Green mica	5.249 Å	9.064 Å	19.991 Å	95°45'
Muscovite <sup>1</sup>	5.19 Å	9.03 Å	20.05 Å	95°46'
Synthetic 2M muscovite <sup>2</sup>	5.189 Å	8.995 Å	20.097 Å	95°11'

The  $b_0$  dimension calculated from the structural formula of the green mica by the method described by Brown (1951, p. 160, 161) is in good agreement with the observed  $b_0$ .

$$\begin{aligned} \text{Calculated: } b_0 &= 9.066 \text{ \AA} \\ \text{Observed: } b_0 &= 9.064 \text{ \AA} \end{aligned}$$

A further difference between the green mica and normal muscovite lies in the relative intensities of the  $00l$  reflections:

	I/I <sub>1</sub>		
	002	004	006
Green mica (oriented aggregate)	100	19	100
Muscovite <sup>1</sup>	95	31	100
Synthetic 2M muscovite <sup>2</sup>	>100	55	>100

The intensities I/I<sub>0</sub> for a mica having the composition of the green mica calculated by the method of Brown (1955) for an oriented aggregate in which 8 per cent of the particles behave as a randomly oriented powder (amount necessary to produce equal 002 and 006 intensities) are as follows:

$$3 \text{ Al:1 Fe in octahedral coordination: } 002(100); 004(23); 006(100).$$

As more iron would tend to depress the intensity of the 004 reflection and the green mica studied has slightly more total iron than the 3:1 ratio used in the calculation, the observed intensity of 19 (for 004) is in good agreement with that calculated.

The  $x$ -ray data for the green mica reveal a larger  $a_0$  and  $b_0$  but slightly smaller  $c_0$  than for the usual muscovite. The  $b_0$  dimension and the relative intensities of the  $00l$  reflections are in close agreement with those calculated for a material of the composition of the green mica.

#### CHEMICAL COMPOSITION

The chemical analysis of the green mica was carried out by standard methods by one of us (MDF) except for determination of Na and K, which were made by means of the flame photometer by Ivan Barlow U. S. Geological Survey. The analysis, which is given in the first column of Table 2, shows the presence of a small amount of TiO<sub>2</sub> and CaO. As the sample contains a small amount of impurities, which are probably

<sup>1</sup> Gillery, 1956.

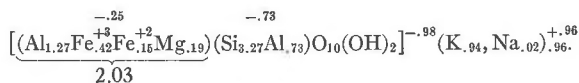
<sup>2</sup> Yoder and Eugster, 1955, p. 246.

TABLE 2. ANALYSIS OF GREEN MICA

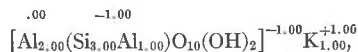
	As determined	Constituents in mica	Adjusted to 100 per cent
SiO <sub>2</sub>	47.28	47.08	47.62
TiO <sub>2</sub>	.30	—	—
Al <sub>2</sub> O <sub>3</sub>	24.46	24.46	24.74
Fe <sub>2</sub> O <sub>3</sub>	8.02	8.02	8.11
FeO	2.52	2.52	2.55
MgO	1.86	1.86	1.88
MnO	.08	.08	.08
CaO	.14	—	—
Na <sub>2</sub> O	.11	.11	.11
K <sub>2</sub> O	10.6	10.6	10.72
H <sub>2</sub> O	4.00	4.00	4.05
F	.14	.14	.14
Total	99.51	98.87	100.00
—O=F	.06		
	99.45		

Specific gravity 2.879.

chiefly sphene and leucoxene, the TiO<sub>2</sub> and CaO reported in the analysis are attributed to these impurities. Sphene and leucoxene also contain SiO<sub>2</sub>, consequently 0.20 per cent SiO<sub>2</sub> was deducted from the SiO<sub>2</sub> reported as attributable to these impurities. The adjusted analysis, calculated to 100 per cent, given in Table 2 column 3, yields the following calculated formula for the green mica,



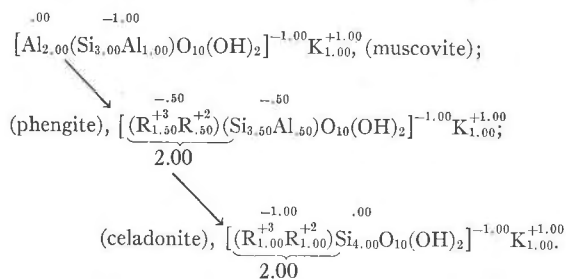
The points of particular interest in this formula, as compared to that of muscovite,



are, (1) the octahedral-tetrahedral charge relation, (2) the higher Si and lower tetrahedral Al, (3) the number of octahedral sites occupied by bivalent cations, and (4) the relatively high Fe<sup>+3</sup> content.

The composition of some of the high silica sericites and their relation to muscovite was explained by Schaller (1950, p. 407-415) as due to their being members of a trisilicic-tetrasilicic series. Foster (1956, p. 67-77) showed that this series, of which muscovite is the trisilicic end member,

is characterized by a gradual shift in the seat of the inherent unit charge from the tetrahedral layers to the octahedral layer. This shift is brought about by the replacement of octahedral aluminum by bivalent cations, usually  $\text{Fe}^{+2}$  and Mg. As this replacement is ion for ion, and the total number of octahedral cations remains the same, there is a deficiency in positive octahedral charges necessary to neutralize the anions associated with this layer, and it develops a negative charge, this charge being the greater the greater the replacement of trivalent cations by bivalent cations. Coincident with this replacement and the development of a negative charge on the octahedral layer, there is an equivalent decrease in the negative tetrahedral charge, due to increase in Si and decrease in tetrahedral Al. Replacement of half the octahedral trivalent cations by bivalent cations produces the tetrasilicic end member, in which all the inherent unit-layer charge is on the octahedral layer, and the tetrahedral layers, completely filled by Si, are neutral, as illustrated below:



In the formula for the green mica from the Grandfather Mountain area, North Carolina, about one-fourth of the negative inherent unit-layer charge of 0.98 is on the octahedral layer—three-fourths on the tetrahedral layers. Thus this mica falls about halfway between muscovite and phengite in its octahedral-tetrahedral charge relationship. The  $\text{R}^{+2}$  ions responsible for the octahedral charge are made up almost equally of Mg and  $\text{Fe}^{+2}$ .

Trivalent iron and total iron are much higher than is usually found in micas in the muscovite-phengite part of the series. As Foster has pointed out, this end of the series is characterized by aluminum; it is the tetrasilicic end of the series that is characterized by iron—both ferric and ferrous. No analysis of a muscovitic mica was found in the literature that contained as much  $\text{Fe}_2\text{O}_3$ , or as much total iron as Fe (7.57 per cent) as was found in this specimen. The highest  $\text{Fe}_2\text{O}_3$  recorded is in an analysis reported by Clarke (1908, p. 286), which reports 6.10 per cent  $\text{Fe}_2\text{O}_3$ . However, as no FeO is reported, this figure probably represents total iron as  $\text{Fe}_2\text{O}_3$  and not necessarily that present as FeO. Total iron as Fe in this analysis is 4.27 per cent, an amount lower than that



found in an analysis reported by Ginzburg (1920, p. 9), which contains 5.64 per cent  $\text{Fe}_2\text{O}_3$ , and 1.27 per cent  $\text{FeO}$ . Total iron as Fe in this analysis is 4.94. A third analysis (Tolman and Goldich, 1935, p. 236) has a higher total iron as Fe content, 5.54 per cent, but is lower in  $\text{Fe}_2\text{O}_3$ , 3.94. Thus the mica herein studied is unique, for its position in the series, in its content of  $\text{Fe}_2\text{O}_3$  and of total Fe.

#### RELATION BETWEEN INDICES OF REFRACTION AND IRON CONTENT

Winchell (1951, p. 368) concluded that the mean index (that is, the intermediate principal index,  $\beta$ ) of muscovitic micas increases rapidly with increase in ferric iron content. Volk (1939, p. 263) agreed with Winchell's conclusion. Both Winchell and Volk used a three component diagram for plotting end member compositions of which the micas studied were presumed to be composed, Winchell using the end members muscovite,  $\text{KAl}_2(\text{Si}_3\text{Al})\text{O}_{10}(\text{OH})_2$ , ferrimuscovite,  $\text{K}(\text{AlFe}^{+3})(\text{Si}_3\text{Al})\text{O}_{10}(\text{OH})_2$ , and picrophengite,  $\text{K}(\text{Al}_{1.5}\text{Mg}_{0.5})(\text{Si}_3\text{Al})\text{O}_{10}(\text{OH})_2$ , and Volk using the end members muscovite, ferrimuscovite, and phengite  $\text{K}[\text{Al}(\text{Fe}^{+2}\text{Mg})](\text{Si}_3\text{Al})\text{O}_9(\text{OH})_3$ . Of these end members only muscovite occurs in nature; the others, ferrimuscovite, picrophengite, and phengite are hypothetical and were postulated for the purpose of interpreting the composition of dioctahedral micas in terms of end members. However, neither Winchell's nor Volk's diagram showed a close relationship between ferric iron content and mean index; both showed considerable scatter of points. None of their micas had as high an index nor as high a content of ferric iron as the green mica herein studied. The relation between the  $\beta$  index and  $\text{Fe}_2\text{O}_3$ , in terms of molecular equivalents and between the  $\beta$  index and  $(\text{Fe}_2\text{O}_3 + \text{Fe})$ , in terms of molecular equivalents in a number of muscovitic micas is shown in Fig. 3. The unnumbered points in this diagram represent micas used by Volk that contained both  $\text{Fe}_2\text{O}_3$  and  $\text{FeO}$ ; the numbered points represent some muscovitic micas reported in the literature for which both analyses and indices of refraction are given. The numbers refer to analyses given in Table 3. Although a very general trend toward increase in  $\beta$  index with increase in  $\text{Fe}_2\text{O}_3$  and with increase in  $(\text{Fe}_2\text{O}_3 + \text{FeO})$  content is suggested, the relationship is not close and it would not be feasible to try to predict even the approximate iron content from the  $\beta$  index or vice versa for muscovitic micas. However, the points representing the much higher  $\beta$  index and iron content of the North Carolina mica are in line with the general upward trend of the points representing these properties in other micas.

#### CAUSE OF COLOR

A semiquantitative spectrographic analysis by John C. Hamilton of the U. S. Geological Survey, shows that the green mica from North

Carolina contains between 0.002 and 0.005 per cent V, between 0.001 and 0.002 per cent Ni, between 0.0005 and 0.001 per cent Cr, and between 0.0002 and 0.0005 per cent Cu. The amounts of these elements present seem too low to account for the color, and Fe remains the most probable cause of the green color in this mica.

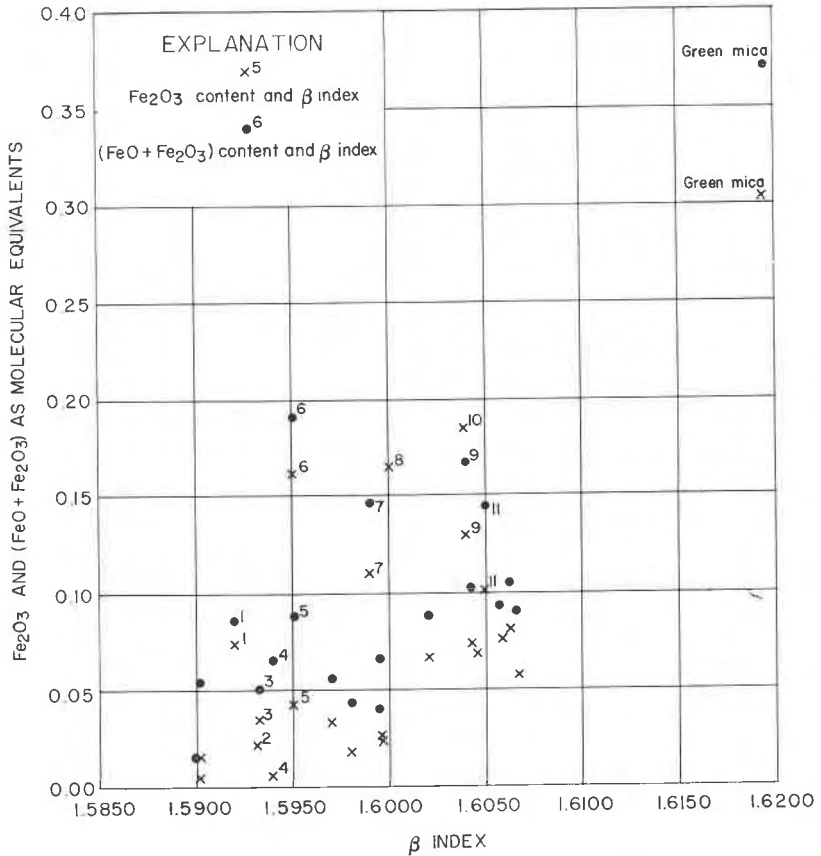


FIG. 3. Relation between  $\text{Fe}_2\text{O}_3$  and  $(\text{FeO} + \text{Fe}_2\text{O}_3)$  content and  $\beta$  index in muscovite micas.

Fersman (1937, p. 201–204) showed that the color of many minerals depends on the relative proportions of different valences of the same atom. Thus, he states that  $\text{Fe}^{+2}$  alone is characterized by yellow-green, and  $\text{Fe}^{+3}$  alone by reddish brown, but that both ions in the same mineral depresses the color to a deep blue or black. Grigoriev and Kotulsky (1941) also found that the presence of  $\text{Fe}^{+2}$  and  $\text{Fe}^{+3}$  together produces a

TABLE 3.—ANALYSES OF MUSCOVITIC MICAS, OTHER THAN VOLK'S, USED IN PREPARATION OF FIGURE 3, ARRANGED IN ORDER OF INCREASING  $\beta$  INDEX

	Per cent										
	1	2	3	4	5	6	7	8	9	10	11
SiO <sub>2</sub>	45.56	44.87	45.12	44.77	45.50	45.84	50.79	43.67	44.73	46.10	45.66
TiO <sub>2</sub>	0.47	0.02	0.51	0.00	0.20	—	1.10	0.72	0.34	2.04	0.31
Al <sub>2</sub> O <sub>3</sub>	35.78	37.72	34.19	35.36	33.20	31.11	26.53	29.76	30.67	30.54	31.80
Fe <sub>2</sub> O <sub>3</sub>	1.92	.54	.85	.28	1.03	4.31	2.94	4.36	3.42	3.43	2.69
FeO	.51	none	.64	2.13	1.41	1.06	1.34	none	1.42	1.96	1.53
MnO	.11	trace	.02	.15	.04	.04	.05	.59	.02	.00	—
MgO	.94	.32	.92	.87	.96	1.10	2.80	1.19	1.56	1.71	.92
CaO	—	.36	.25	.00	trace	trace	—	.06	none	.07	.09
Na <sub>2</sub> O	1.07	1.04	.71	.95	.52	2.27	1.01	.54	.53	3.82	.60
K <sub>2</sub> O	10.03	9.83	10.33	10.81	10.49	9.66	9.71	10.00	10.18	6.54	10.34
H <sub>2</sub> O—		.38	1.57		1.10			2.24	1.43		.36
H <sub>2</sub> O+	3.72	4.72	5.05	4.54	5.37	4.49	3.90	6.28	5.17	3.83	5.32
F	—	n.d.	.05	.15	.18	.15	—	.95	.02	.05	.37
Total	100.11	100.24 <sup>1</sup>	100.32 <sup>2</sup>	100.01	100.12 <sup>3</sup>	100.03	100.17	100.41 <sup>4</sup>	100.23 <sup>5</sup>	100.09	99.99
$\beta$ index	1.592	1.5930	1.5932	1.5938	1.595	1.595	1.599	1.595— 1.607	1.604	1.604	1.605— 1.606

<sup>1</sup> Includes 0.27 per cent Cr<sub>2</sub>O<sub>3</sub>, 0.09 per cent V<sub>2</sub>O<sub>5</sub>, 0.08 per cent P<sub>2</sub>O<sub>5</sub>, and trace of Li<sub>2</sub>O.

<sup>2</sup> Includes 0.01 per cent V<sub>2</sub>O<sub>5</sub> and 0.10 per cent P<sub>2</sub>O<sub>5</sub>.

<sup>3</sup> Includes 0.04 per cent BaO, 0.05 per cent P<sub>2</sub>O<sub>5</sub>, and 0.03 per cent S.

<sup>4</sup> Includes 0.05 per cent BaO.

<sup>5</sup> Includes 0.66 per cent BaO, 0.02 per cent V<sub>2</sub>O<sub>5</sub>, 0.03 per cent P<sub>2</sub>O<sub>5</sub>, and 0.03 per cent S.

1. Claro, Tessin, Jakob, 1925, p. 445, no. 11.

2. Whitcombe Valley, Mikonui, New Zealand, Hutton, 1940, p. 330B.

3. Duffer Creek, Westland, New Zealand, Hutton, 1940, p. 330B.

4. Finnbo, Dalecarlia, Sweden, Eckermann, 1927, p. 231.

5. Mariner's Peak, South Westland, New Zealand, Hutton and Seelye, 1945, p. 161.

6. Mausjö Mountain, Sweden, Eckermann, 1927, p. 231.

7. Rossa, Val Calanca, Tessin, Jakob, 1925, p. 445, no. 18.

8. Utevis district, Jokkmokk, Sweden, Ödman, 1950, p. 18.

9. Henry Pass, George Sound, New Zealand, Hutton and Seelye, 1945, p. 161.

10. Wissahickon Valley, Philadelphia, Pa., Postel and Adelhelm, 1944, p. 285.

11. Mattawan Township, Nipissing District, Ontario, Ferguson, 1943, p. 40.

darker color than either alone. Depth of color produced by  $\text{Fe}^{+2}$  and  $\text{Fe}^{+3}$  together, or by either alone, also depends on the amounts present. Another factor affecting the color produced by coloring ions in minerals is crystal structure (Grum-Grzhimailo, 1945, p. 933-46). Iron is responsible for green colors in biotites (Hall, 1941, p. 29-33) and for the green color in glauconite. In both of these minerals Fe is usually present both as  $\text{Fe}^{+2}$  and  $\text{Fe}^{+3}$ . Wyoming bentonite, which consists almost entirely of montmorillonite, is olive-green when  $\text{Fe}^{+3}$  predominates over  $\text{Fe}^{+2}$ , but is blue-gray when  $\text{Fe}^{+2}$  predominates over  $\text{Fe}^{+3}$  (Foster, 1956, 1003). In glauconite also,  $\text{Fe}^{+3}$  is ordinarily in excess of  $\text{Fe}^{+2}$ . As these minerals have the same crystal structure as the mica from North Carolina, it is concluded that its green color is due to the presence of both  $\text{Fe}^{+3}$  and  $\text{Fe}^{+2}$ , with  $\text{Fe}^{+3}$  predominant over  $\text{Fe}^{+2}$ .

#### SUMMARY

A detailed study of a green mica associated with metamorphosed arkoses and arkosic quartzites in the Grandfather Mountain area, North Carolina, showed it to be a dioctahedral potassium mica about midway between muscovite and phengite in its layer charge relationship. For its place in the trisilicic-tetrasilicic dioctahedral mica series, this mica is unusually high in content of ferric iron and of total iron. Its high indices of refraction are attributed to this high iron content, and its color is attributed to the presence of both  $\text{Fe}^{+3}$  and  $\text{Fe}^{+2}$  in the structure, with  $\text{Fe}^{+3}$  predominant over  $\text{Fe}^{+2}$ .

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