

MANGANIFEROUS MICAS FROM MADHYA PRADESH, INDIA

BY SRIPADRAO KILPADY, F.A.Sc. AND A. S. DAVE

(University Department of Geology, Nagpur)

Received August 22, 1953

IN his classic Memoir on the Manganese Ore Deposits of India, Dr. Fermor (1909, pp. lxxii, 9) has recorded the occurrence of a large number of micaceous minerals particularly from the Gondite Series of Madhya Pradesh, and suggested the possibility of some of them turning out to be new to science. In the absence of chemical analyses and detailed optical investigations, he provisionally assigned some of the pink and brown micas to the Alurgite and Manganophyllite species.

The need for a thorough re-examination of the micaceous minerals was brought home to the senior author when he had occasion to examine from time to time the large collections from the Sausar Series made by the post-graduate students of the Department in the course of their field-survey camps during the sessions 1949-53. The large number of micaceous minerals in this collection received at the hands of the students nothing more than a routine optical examination and a tentative identification of Alurgite (?).

The recent publication of a note on the manganiferous micas of India by Bilgrami (1952, pp. 42-43) and the comments thereon by Dr. Fermor (1952, p. 128) again drew our attention to our comprehensive collection and the need for a thorough chemical and optical investigation of the micaceous minerals. This study was undertaken when the junior author joined the Department as a research scholar at the commencement of the last academic session.

In our collection there are atleast four different types of micaceous minerals: a brown (variegated) to bronze coloured mica which has now been definitely identified as Manganophyllite; a crimson-pink variety whose identity with Alurgite has now been established; a pale greenish coloured species which is perhaps a chlorite or altered mica; and a dark brown type which may turn out to be another variety of Manganophyllite. This paper contains a detailed account of the chemical and optical investigation of the manganiferous micas: Manganophyllite and Alurgite.

Dr. Fermor (1909, pp. 196-97) has reported the occurrence of brown micas (Manganophyllite?) from Sithapathur in the Bhandara District and

from Ghogara, Junawani, Kacharwahi, Pali, Ramdongri and Satak in the Nagpur District. Alurgite (?) has been reported by him from Sithapathur (Bhandara District) and Ghogara and Kacharwahi from the Nagpur District.

The brown and crimson-pink micas in our collection come from the following localities:—

- Brown mica . . . Khapa, Nagpur District;
 Brown and crimson-pink mica . . . Sithapathur and Chikhla, Bhandara District; Tirodi, Balaghat District.

The brown and the crimson-pink micas which form the subject of this paper come from the Chikhla area of Bhandara District. Both the micas occur in a coarse pegmatite cutting across the manganese ore body in the Sitasongi mine. Above the 140' level the pegmatite thins off into a vein hardly a foot or two in width, while at deeper levels it widens considerably. Good specimens of the two varieties of mica—brown and crimson-pink—were collected from the pegmatite at the 60' level—the identical locality from which Bilgrami (1952, p. 42) got his specimens. The brown mica occurs in fairly big books sometimes 7–8 inches across and 2–3 inches thick, while the crimson-pink type occurs only in small flakes and scales. Both these types are found in the same pegmatite and sometimes interlaminated with each other.

MANGANOPHYLLITE

Physical characters.—Crystals monoclinic with hexagonal outlines; usually massive lamellar. Highly perfect basal cleavage and prominent parting or secondary cleavage parallel to 010 yielding and breaking into long narrow strips. Regular percussion and pressure figures are also obtained. Specific gravity 2.98. Lustre is almost bronzy to metalloidal and submetallic on cleavage surfaces.

Optical properties.—The optic axial plane is parallel to 010. The prominent parting parallel to 010 which corresponds to the prominent ray of the percussion figure was made use of in the orientation in the absence of well-defined crystals. The acute bisectrix X is almost normal to 001. Optically negative. Mean refractive index: $\beta = 1.60-1.61$. Strong birefringence in transverse sections and weak birefringence in basal sections. The value of the birefringence as determined by the Berek's compensator in transverse sections was $\gamma - \alpha = .045-.048$ and in basal sections was: $\gamma - \beta = 0.0056$. The optic angle as determined by direct rotation from one optic axis to another on the 5-axes universal stage was $(2V) = 35^\circ 30'$.

The colour is not uniform and varies from place to place; in fairly thick books and plates it is dark brown to bronzy; in thinner plates it is reddish brown and in thin flakes it is often a reddish brown and sometimes a dirty yellowish brown. Strongly pleochroic in thin section with X = Honey yellow to pale yellow; Y = Light brown; Z = Dark brown with often a tinge of red. Absorption $X < Y < Z$ and maximum parallel to cleavage lines. Parallel extinction, transverse sections showing a mottled appearance between crossed nicols.

Sometimes what appear to be tiny inclusions of a blood red flaky mineral are found in the manganophyllite. The biaxial character and the fact that the acute bisectrix X is normal to 001 indicate that perhaps these are inter-laminated flakes of the crimson-pink mica Alurgite. Well-defined hexagonal outlines in some of them support this conclusion.

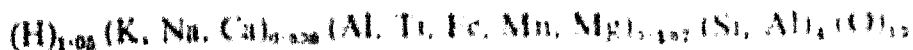
Composition.—The average of three chemical analyses of the manganophyllite is given in Table I.

TABLE I

Constituents	Weight %	Mol. Prop.	Oxy. Atoms	Metal Atoms
1	2	3	4	5
SiO ₂ ..	40.6	.677	1.354	2.929
Al ₂ O ₃ ..	16.7	.164	.492	1.419
TiO ₂ ..	1.0	.013	.026	.056
Fe ₂ O ₃ ..	5.1	.032	.096	.277
MnO ..	5.58	.079	.079	.3918
CaO ..	0.78	.014	.014	.0605
MgO ..	20.33	.501	.501	.2164
H ₂ O ..	2.2	.122	.122	1.05
K ₂ O ..	8.4	.089	.089	.7702
	100.69	..	2.773	..

The values in the last column of the table are calculated by multiplying the atomic proportion of elements in the oxides by a factor obtained on dividing the total number of oxygen atoms in the structural unit of mica (*i.e.*, 12) by the total of oxygen atoms obtained (*i.e.*, 2.773). The conclusions based on the X-ray analyses of micas (Bragg, 1937, pp. 37-38) indicate that Si is replaced in part by Al in the silica tetrahedrons; Al, Fe, Mg and

Mn occupy positions in 6 co-ordination, interchangeable to some extent and that K, Na and Ca occupy positions in 12 co-ordination, interchangeable in themselves. On the basis of this the formula of the manganophyllite may be expressed as follows:



The general formula for Biotite and Phlogopite micas according to Bragg (1937, p. 215) is: $(X)_{0.4} (Y)_3 (Al, Si)_4 (O)_{10} (O, H, F)_2$, where X = K, Na, Ca, . . . etc., Y = Al, Mg, Fe, Fe, Cr, Mn, Ti

In the above formula the number in the Y position appears to be in the neighbourhood of three. In the formula of Manganophyllite also it can be seen that the number in the Y position is 3.187 and therefore indicative of its close affinity with Biotite.

It can be seen from Table II that the Manganophyllite from Sitasonggi approaches very closely the Manganophyllite from Långban, Sweden, but for a higher percentage of MgO in our specimen. A comparison of the Sitasonggi mica with the average chemical analyses of Biotite and Phlogopite (Nos. 5 and 4 in Table II) shows that the average Biotite contains a much higher percentage of iron and a much lower percentage of magnesia, while the Phlogopite analysis shows very little iron and a slightly higher MgO content. Since the Phlogopite analysis appears to be closer to the Manganophyllite than that of the Biotite, it may possibly indicate that Manganophyllite may perhaps be considered a variety of Phlogopite, where a part of the MgO is replaced by MnO resulting in the formation of a manganophlogopite. Perhaps a serious objection to this interpretation would be that Phlogopite is rare in igneous rocks but it should be remembered that the pretty high magnesia content of the Sitasonggi and Pajsberg Manganophyllites cannot otherwise be explained.

In Diagram I is indicated the position of our Manganophyllite with reference to the Phlogopite-Eastonite-Siderophyllite-Annite series of Biotite micas. It is seen that the Manganophyllite is close to the Phlogopite-Eastonite series and closer to the Phlogopite than the Eastonite.

The optical properties of the Manganophyllite such as the dark colour, strong pleochroism and refractive index agree with that of ordinary Biotite. The optic angle (2V) is 35° 30' in our specimen while in ordinary Biotite it is 0° or very near 0°. In rare types however the angle is said to be as high as (2V) = 44°. Dr. Fermor (1909, p. 196) has recorded that some of the brown micas which he grouped under Manganophyllite (?) were uniaxial and others biaxial and suggested the possibility of there being atleast two

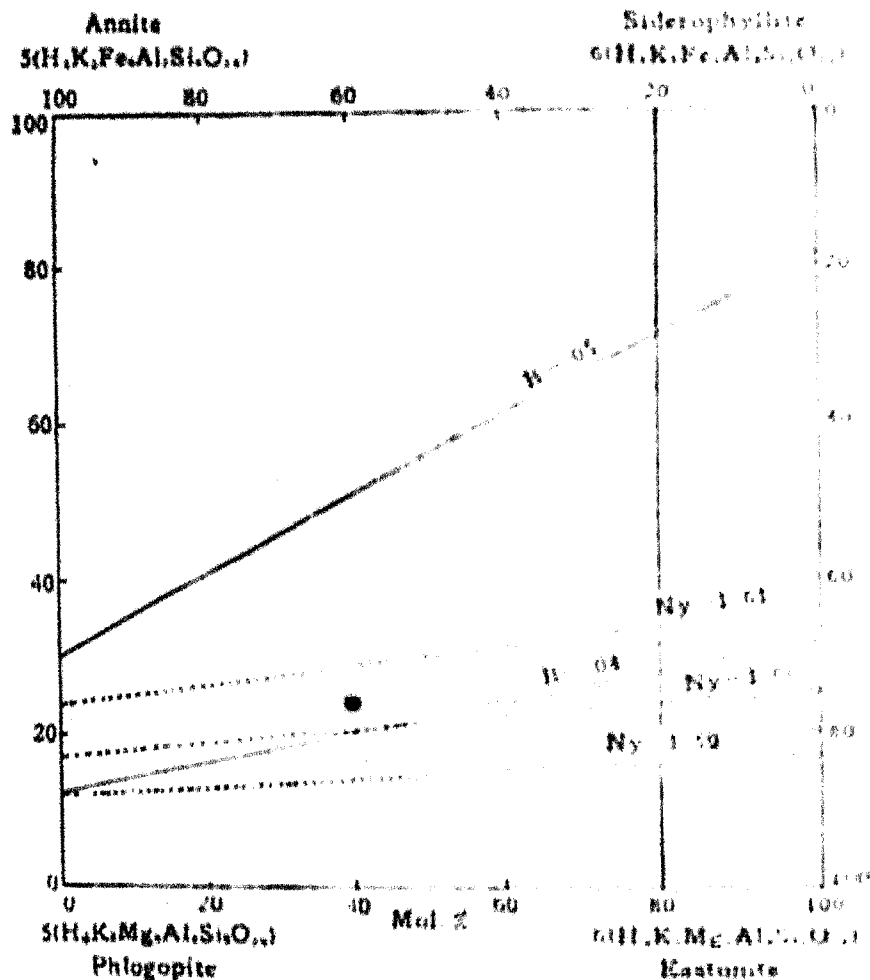
TABLE II

Constituents	Manganophyllite, Sitasaongi	Manganophyllite, Bhang	Manganophyllite, Pajaberg	Phlogopite, Burgess	Biotite, average of 51 analyses
	1	2	3	4	5
SiO ₂	40.6	41.36	40.64	39.66	36.46
Al ₂ O ₃	16.7	16.02	9.43	17.00	17.15
TiO ₂	1.0	..	..	.56	1.25
Fe ₂ O ₃	5.1	4.66	3.66	.27	8.17
FeO	..	..	..	.20	14.46
MnO	5.58	5.41	9.68	..	.56
CaO	.78	..	..	..	.98
BaO	..	..	..	.62	..
MgO	20.53	13.27	22.31	26.49	8.70
H ₂ O	..	..	.29	..	..
K ₂ O	8.40	11.43	10.50	9.97	8.23
Na ₂ O	..	2.09	.35	.60	.91
H ₂ O	2.2	4.62	4.30	2.99	2.87
P	..	0.49	0.30	2.24	.18
	100.60	99.35	101.46	100.60	99.92

Note
 Analysis No. 1 by Sahu, S. K. and Dave, A. S.
 Analysis No. 2 by Flink, A. H., *Stockh. Blang*, 1888, 13 (2).
 Analysis No. 3 by Hamberg, G., *For. Forh.*, 1890, 12, 567.
 Analysis No. 4 by Clark & Schneider, 1890, 40, 410.
 Analysis No. 5 by Rankama, K. & Sahama, Th. G., *Geochem.*, 1950.

species. Our observations also confirm this possibility. The Manganophyllite from the Sitasaongi area has an optic angle range between 35° and 36° (2 V) only. The value of the axial angle for the same mica as reported by Bilgrami (1952, p. 43) is 18°-22° (2 V).

The dark brown mica from Sithapathur, Bhandara District, classed under Manganophyllite (?) by Dr. Fermor (1909, p. 197) and said to be uniaxial has been examined by us and found to exhibit a small optic angle ranging up to about 10° (2 V). In the absence of a chemical analysis it is



difficult to say whether this is another distinct species of Manganophyllite, different from the Sitasaongi specimen. Perhaps it is another species.

The optic properties of the micas vary with the composition and it is known that the optic angle in varieties of Biotite increases with the iron content. Heinrich (1946, p. 847) says that in the Biotite-Phlogopite series, the index of refraction is affected more by increments of Fe_2O_3 and TiO_2 than FeO . He has found that the effect of the ferric iron and the titanium is about twice that of the ferrous iron and the refractive index of a few Manganophyllites when plotted were found to fall reasonably close to the curve and indicate that the effect of the manganese is less than that of the ferrous iron. Our Manganophyllite when plotted according to Heinrich's method shows that the refractive index is in agreement with the chemical composition. In view of the very low percentage of iron in our Manganophyllite the reason for the medium value of the optic angle has to be perhaps attributed to the manganese

content. Siderophyllite (Coats and Fahey, 1944, p. 373) with 1.01 MnO has $2V = 6$ to 8° ; Manganophyllite (Larsen and Berman, 1934, p. 238) with 4.52 of MnO has an angle of 14° ; a very rare type of Biotite found at Långban, Sweden (Jakob, 1924, p. 155) with 8.30 Mn_2O_3 is said to have $2V = 33-30^\circ$.

In conclusion it may be said that the Sitasongi Manganophyllite comes very near the Långban species (*cf.* Table II) and that the provisional identification by Dr. Fermor of the Bronze-brown micas as Manganophyllite has been completely substantiated by our detailed chemical and optical investigations. It may also be concluded that the Manganophyllite does belong to the Biotite group, its affinity however being closer to Phlogopite-Eastonite rather than ordinary Biotite.

ALURGITE

Physical characters. Usually occurs in small flakes and scaly massive. Crystals have not been noticed. Also in small plates and books not more than 1.5 inches across. Perfect basal cleavage and pronounced parting parallel to 100 (*b*). The presence of the latter yields long and narrow strips. Characteristic percussion figures are also obtained. Specific gravity 2.90. Lustre pearly on cleavage faces. Streak pale to light rose.

Optical properties. The optic axial plane is parallel to 100. The acute bisectrix X very slightly deviates from the normal to 001. Optically negative. Mean refractive index $\beta = 1.62-1.63$. Birefringence high in transverse sections ($\gamma - \alpha = .038-.04$) (could not be accurately measured by the Berek's compensator, as it was difficult to determine the position of compensation correctly) and weak in basal sections ($\gamma - \beta = .0023$). The axial angle ($2V$) is $29-15^\circ$.

The colour in fairly thick plates is almandine to copper red; in thin scales it is pinkish to crimson (pale) with a tinge of purple. Pleochroism distinct: X - Pale pink; Y - Copper red; Z - Light brownish red. Absorption X - Y - Z. Straight extinction. Mottled appearance between crossed nicols in transverse sections.

Composition. Table III gives the average of three chemical analyses of the Alurgite from Sitasongi. The calculated formula for the mica is: $(H)_{1.997} (K, Na, Ca)_{.003} (Al, Fe, Mg, Mn)_{2.061} (Si, Al)_4 (O)_{12}$.

The general formula for Muscovite and Margarite as given by Bragg (1937, p. 215) is: $(X)_{n-1} (Y)_2 (Al, Si)_4 (O)_{10} (O, H, F)_2$, where the value of Y is in the neighbourhood of 2. In the formula of Alurgite given above the value of Y comes to 2.061, indicating its affinity with the muscovite group.

TABLE III

Constituents	Weight %	Mol. Prop.	Oxy. Atoms	Molec. Atoms
1	2	3	4	5
SiO ₂	45.8	.76	1.52	3.111
Al ₂ O ₃	29.6	.29	.87	2.373
Fe ₂ O ₃	5.8	.036	.108	0.291
MnO	1.07	.015	.015	.0414
CaO	.98	.018	.018	.0527
MgO	2.23	.056	.056	.1749
K ₂ O	9.5	.101	.101	.6268
H ₂ O	4.4	.244	.244	1.997
	99.18	..	2.932	..

In Table IV are given the analyses of Alurgites from Sweden, Piedmont and Sitasaongi together with the average analysis of 37 Muscovite specimens. A glance at the table shows the very close similarity of the Sitasaongi specimen with that from Sweden, and also that the Alurgites are near to the Muscovite group.

According to Winchell's (1925, p. 415 and 1942, p. 114) revised classification of the micas the position of our Alurgite from the point of view of the chemical composition falls near his Picrophengite (see Diagram II).

The refractive index β of the Sitasaongi Alurgite is 1.62-1.63 while that of the Alurgite from the Ultevis District Jokkmokk, North Sweden, (Odman, 1950, *Min. Mag.*, 1952, p. 473) containing 0.59% MnO is 1.59-1.607; the refractive index β of the specimen from St. Marcel, Piedmont, Italy (Dana, 1948, p. 666) is 1.59. The optic axial angles (2V) of these specimens are as follows: Sitasaongi specimen 29° 15'; Swedish specimen 38°-39°; Piedmont specimen: 34°-35°.

It is seen that the Sitasaongi Alurgite comes close (see Table IV) to the Swedish specimen but for slightly higher amounts of iron and MgO, which as has already been remarked account for the higher refractive index and lower (2V) axial angle in the former specimen.

TABLE IV

Constituents	Alurgite, Sitasaongi	Alurgite, Sweden	Alurgite, Piedmont	Muscovite, Average of 37 analyses
1	2	3	4	5
TiO ₂	45.6	43.67	53.22	44.95
Al ₂ O ₃	29.6	29.76	21.19	33.51
Li ₂ O	..	.72	..	.41
Fe ₂ O ₃	5.8	4.36	1.22	1.76
FeO	..	..	..	.64
Mn ₂ O ₃	1.07	..	0.87	..
MnO		0.59	0.18	.05
CaO	.98	0.06	..	.37
BaO	..	0.05	..	..
MgO	2.23	1.19	0.02	0.81
K ₂ O	9.5	10.00	11.20	10.47
Na ₂ O	..	.54	.34	1.32
H ₂ O*	4.4	6.28	5.75	5.30
H ₂ O	..	2.24	..	..
F	..	0.05	..	0.13
	100.18	100.41	99.90	99.72

Note—Analysis No. 1 by Sahu, S. K. and Dave, A. S.

Analysis No. 2 by Odman (01 of 11), *Mtn. Mag.*, 1952, 29, 217, 473.

Analysis No. 3 by Penfield, S. L., *Am. J. Sc.*, 1893, 46, 288.

Analysis No. 4 by Rankama, K. and Sahama, Th. G., *Geochemistry*, 1950.

Dana (1892, p. 635) said that Alurgite may be identical with Manganophyllite, and classed it along with the biotite-phlogopite micas. Winchell (1951, p. 365) classes it as a manganian phengite, and our studies point to its being a manganian pierophengite.

In conclusion it may be stated that the tentative grouping of the crimson and pink micas by Fermor under Alurgite (?) has now been proved to be entirely correct. The Sitasaongi pegmatite contains both the Alurgite and Manganophyllite micas. Dr. Fermor's (1952, p. 129) opinion that the Alurgite described by Bilgrami (1952, p. 42) is perhaps only Manganophyllite appears to us to be substantiated by our studies. However, there is no doubt

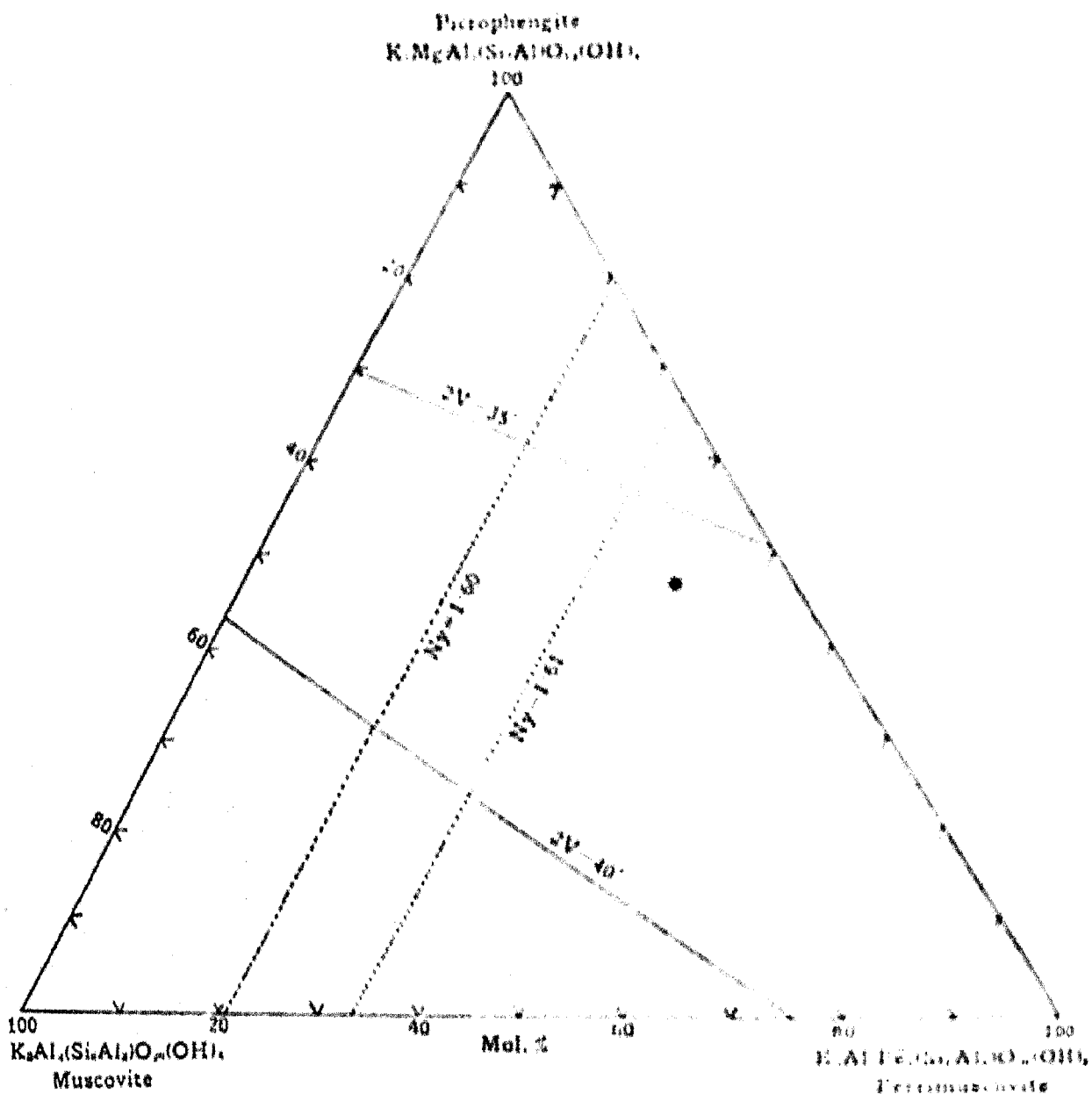


Diagram II. (After Winchell)
Position of Alurgite in the Muscovite Group

whatsoever, that undoubted Alurgite and Manganophyllite occur in close association in the Sitasongi pegmatite. The original micas in the pegmatite appear to have been Biotite and Muscovite, the former being the first to crystallise and hence occurring in pretty big books and plates and the latter appeared later in smaller flakes and scales. The replacement of Fe by Mn is the most common and geochemically the most important among the various possibilities (Rankama, 1950, p. 645), in the pneumatolytic-hydrothermal

phases of pegmatite intrusion. The dark silicate minerals like Biotite which contain hydroxyl groups in their structure are the ones usually liable to such replacement. It may, therefore, be said that Manganophyllite and Alurgite have perhaps resulted from the diadochic replacement of Fe by Mn, in the original Biotite and Muscovite of the Sitasaongi Pegmatite, during the hydrothermal stage of crystallisation.

Our thanks are due to Mr. S. K. Sahu, Analyst, Laxminarayan Institute of Technology, Nagpur University, for assistance in the analytical work.

SUMMARY

The bronze-brown and crimson-pink Micas of the Sausar Series, from the Chukhla area, in Bhandara District, have been investigated and their optical and chemical characteristics have been recorded for the first time and discussed in detail. They are found to belong to the Manganophyllite, and Alurgite species and exhibit close affinities with similar species reported from Sweden. These Manganiferous micas of Madhya Pradesh have obviously resulted from the diadochic replacement of Fe by Mn in the original Biotite and Muscovite of the Sitasaongi pegmatite, during the hydrothermal phase of crystallisation.

REFERENCES

- Bilgrami, S. A. *Curr. Sci.*, 1952, **21**, 42.
 Bragg, W. L. *Atomic Structure of Minerals*, 1937.
 Chitovskis, P. *Neues Jahrb. Mineral Geol. Referate*, 1931, **2**, 160.
 Coats, R. R. and Falvey, J. J. *Am. Mineral*, 1944, **29**, 373.
 Cross, W. *Amer. Journ. Sci.*, 1897, **4**, 115-141.
 Dana, F. S. *A Text-Book of Mineralogy*, 4th Ed., 1948.
 Dana, J. D. *System of Mineralogy*, 6th Ed., 1892.
 Fernor, I. L. *Mem. Geol. Surv. India*, 1909, **37**; *Curr. Sci.*, 1952, **21**, 128.
 Heinrich, F. Wm. *Am. Journ. Sci.*, 1946, **244**, 847.
 Jakob, J. *Zeit. Krist.*, 1924, **61**, 155.
 Johannsen, A. *A Descriptive Petrography of Ign. Rocks*, 1932, **2**.
 Larsen, F. S. and Berman, H. *Microscopic Determination of Non-Opaque Minerals*, 2nd Ed., 1934.
 Mathews, E. H. *Journ. Geol.*, 1900, **8**, 221.
 Odman, O. H. *Min. Mag.*, 1952, **29**, No. 217, 473.
 Rankama, K. and Sahama, Th. G. *Geochemistry*, 1950.
 Termier, P. *Compt. Rend.*, 1902, **134**, 371-73.
 Tschermak, G. *Zeit. Fur. Krist.*, 1879, **3**, 132.
 Winchell, A. N. *Am. Journ. Sci.*, 1925, **209**, 309, 415.
 *Ibid.*, 1942, **28**, 114.
 *Elements of Optical Mineralogy*, 4th Ed., 1951, **2**.