

The crystallographic measurements of johannite and "gilpinitite" were made on crystals of the order of .5 mm in length. Only one of the three crystals measured had sufficient forms to permit the calculation of the axial ratios which was accomplished by the use of the forms  $c$ ,  $a$ ,  $b$ ,  $k$ , and  $p$ , that is, by all of the forms observed on the measured crystal. These forms had each but one face represented on the crystal with the exception of  $b$  and  $a$ , which had two. The axial ratios obtained in this way fit rather closely the observed values of Ježek, whose angles were not used in the calculations. Table 2 shows the close agreement of the calculated angular values with those observed by him. The forms  $d(230)$ ,  $f(10.13.0)$ ,  $w(2\bar{1}0)$ ,  $n(\bar{1}11)$ ,  $r(251)$ , were not observed by the authors, the angles of these forms are therefore taken from Ježek's paper. The letters used to indicate the various forms are likewise taken from Ježek, with the exception of the three pinacoids  $c$ ,  $a$ , and  $b$ , and the prism  $w$ .

In the last column of Table 2 are listed the observed angles for "gilpinitite" which are seemingly sufficient to establish the crystallographic identity with johannite.

## PURPLE MUSCOVITE FROM NEW MEXICO\*

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Purple muscovite of various shades and presenting unusually attractive and striking color effects occurs abundantly in northern New Mexico as a constituent of pegmatite dikes. The purple color of the mica suggests lepidolite or some mica other than muscovite. The results obtained, however, have shown that this mica is normal muscovite in all its properties except that of color. The pleochroism is strong in basal cleavage pieces and, on comparison, it was found that other strongly colored micas are much more pleochroic in basal sections than commonly recognized. A brief examination, made for comparative purposes, of baddeckite from Nova Scotia, supposed to be a muscovite with considerable iron replacing the alumina, has led to the suggestion that the material analyzed and described was not a mica but a mixture of hematite and a clay.

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The locality of the purple muscovite is in southwestern Taos County, New Mexico, in R. 11 E., T. 23 N., about sixteen miles SSW of the city of Taos and about thirty-seven miles east of north of Santa Fe, as measured in a straight line on the map, but in actual travel the distance is nearly twice as far. The purple muscovite is most abundant at the Harding mine which lies about nine and one half miles due east of Embudo as measured on the map and about thirteen miles as traveled. The mine is about half way between Picuris and Barranca. A deeper colored muscovite was collected from near the summit of the south bank of the Rio Grande River, about three miles NW of the Harding mine, and a mile or so SW of Pilar (Cieneguilla). This occurrence will be referred to as that of Pilar.

Samples of the muscovite from Pilar had been submitted for identification several years ago by Mr. James A. Burton of Embudo, New Mexico, and recently samples from the Harding mine were brought in by Mr. N. H. Darton of the U. S. Geological Survey.

In this region according to Mr. N. H. Darton, there is a pre-Cambrian complex from five to ten miles across, composed of schists, quartzites and probably other rocks. In this complex there are pegmatite dikes, ranging from less than a foot to probably more than a hundred feet in thickness. The Harding mine, locally known as the glass mine, is located on one of the large dikes which intrudes a dark colored schist containing much biotite and tourmaline. In this dike there were several large lenses of pure lepidolite, a mineral mined and shipped for use in the glass industry.

The dike also contains large quantities of spodumene, albite, and muscovite, as well as quartz and microcline. Apatite, garnet, columbite, and probably other minerals are present in smaller quantities. The albite, muscovite, and the lithium minerals have replaced the feldspar and quartz and there is a definite genetic relation in the dike between the different minerals. It is very evident that the purple muscovite has encroached upon, and more or less replaced, the other minerals so that these, too, take on some shade of purple, depending on the quantity of muscovite present. No tourmaline was found in the dike, neither was graphic granite encountered.

Purple, as a general term, describes the color of most of the specimens of muscovite although variations which range from

almost a pink through magenta to a deep violet are common. Many of the mica specimens are lilac in color, and on comparison a polished specimen of the mica is almost identical in shade and tint with a crystal of the lilac colored spodumene (kunzite) from southern California. It seemed best, however, to use the more general term purple which includes all the different shades involved.

A more accurate definition of the average color would be closely represented by Ridgway's "Eupatorium Purple" and "Daphne Pink," Plate XXXVIII. Smaller seams of the mica in white albite are perhaps better matched by Ridgway's "Rosolane Purple," Plate XXVI, especially the light and pale colors of the plate. A few specimens are almost a "Rosolane Pink." Where muscovite has replaced microcline, forming a compact fine-grained mass, darkened by black oxide of manganese, the specimens resemble the darker purples and violets of Plates XI and XXV. The muscovite from Pilar is much deeper colored than that from the Harding mine and carries the suggestion of a bronzy red or a coppery red color, agreeing with Ridgway's "Bordeaux," Plate XII, grading off into the adjacent colors. The streak (powder) of the mica from the Harding mine is white with a faint suggestion of a lilac tint, whereas that of the muscovite from Pilar is "Pale Vinaceous Lilac" (Ridgway), Plate XLIV. The streak of the muscovite from Pilar, compared to that from the Harding mine, shows a decided color.

The purple muscovite in the Harding mine is widely disseminated throughout the dike but at no place does it form large masses. No single mass of muscovite more than a foot thick was seen, though seams and aggregates several inches thick are abundant. The individual scales of the mica crystals range in size up to about half an inch across. They show no crystal boundaries, although many of the scales show a tendency toward the hexagonal form.

A more or less definite order of minerals can be observed in the walls of the open cuts of this mine. Massive white quartz which at places reaches a vertical thickness of about ten feet lies at the top. At many places where no mining has been done, large areas of the surface are covered with boulders of such quartz. It does not, however, extend universally over the pegmatite for at one place the quartz-feldspar pegmatite is in direct contact with the schist, with no massive quartz between. At this place seams and disseminated scales of lepidolite in the pegmatite extend to within a foot of the schist-pegmatite contact. But the absence of massive

quartz and the closeness to the pegmatite-schist contact of any lithium minerals are rare occurrences and in most places the cap of massive white quartz is characteristic.

Under this massive quartz is a zone of from ten to twenty feet in thickness of a mixture of white to gray massive quartz with numerous nearly vertical spodumene crystals which reach a length of ten feet, a width of one foot, and maximum thickness of not over one inch. Although the spodumene crystals are characteristically nearly vertical in the upper portion of this zone, many of them are irregularly oriented and in the lower portion they lie horizontally or inclined in various directions. Masses of darker colored quartz with smaller crystals of spodumene, oriented in various directions, are also present.

Below the spodumene zone is one characterized by an abundance of purple muscovite with white albite, white quartz, and yellowish or tawny colored crystals of spodumene, much smaller than those just described. If spodumene is absent, and the association is albite, quartz, and lepidolite, the lithium mica forms thin prismatic crystals, reaching a length of several inches and perhaps on the average about one twenty-fifth of an inch thick. These albite-quartz-lepidolite mixtures form curved masses, the mica prisms, slightly radiating, being approximately vertical. The strikingly colored aggregate of purple muscovite, yellowish spodumene, white albite and quartz, is remarkably free from any microcline as seen in the hand specimen, but a microscopic examination of thin sections of the finer grained compact muscovite shows residua of microcline full of minute shreds of the replacing mica. These compact masses of muscovite are generally of a darker shade than the coarser more granular mica.

In the western portion of the dike this muscovite-spodumene-albite-quartz aggregate is not well developed and its place seems to be taken by a microcline-spodumene mixture, both being slightly replaced and colored purplish by the incoming muscovite. The microcline especially is of an attractive purplish pink color, a most unusual shade for feldspar. Below this purplish microcline-spodumene mixture there seems to be another zone of muscovite-spodumene-albite-quartz but the exposures were insufficient to definitely establish this last relationship.

Below these strikingly colored mineral aggregates lies lepidolite, as small scales mixed with the other minerals and in greater

quantity when mixed with only albite or albite with a little quartz. Lepidolite becomes more abundant in a downward direction and the mixture of lepidolite and other minerals grades into a zone or set of lenses of nearly pure lepidolite, which is the material mined and shipped. It is reported that a zone of purplish microcline and spodumene, similar to the one mentioned above, was encountered below the zone of lepidolite lenses. Muscovite is practically absent in the zone where lepidolite is abundant. Though the lepidolite is purple, it generally has a more bluish tint than the muscovite and by this difference in color one mineral can readily be distinguished from the other.

The minerals in the pegmatite at the Harding mine—microcline, muscovite, spodumene, albite, quartz, and lepidolite, with smaller quantities of other minerals—are considered to be largely the product of a replacement process. In such a process, the muscovite has a definite position, coming in with the albite after the spodumene and before the lepidolite. Muscovite definitely replaces microcline and spodumene and probably also albite and quartz and together with these minerals is itself later probably replaced by lepidolite. In places it forms seams in the spodumene and the albite but it is especially prone to develop along their boundaries. A more detailed description of this dike and its minerals and genetic relations, is being prepared.

The deeper colored muscovite from near Pilar occurs disseminated through small quartz-microcline pegmatite dikes that cut the pink micaceous quartzite of the pre-Cambrian complex already mentioned. According to Mr. J. A. Burton, there are several dozen dikes containing the reddish purple mica and these dikes range in thickness up to several feet. One dike, from which the material examined was collected, is irregular in size and shape and from six inches to a foot in thickness. The dike is nearly vertical but inclines toward the west and cuts across the structure of the quartzite. The contact of the dike and quartzite as seen in the field was sharp and no difference could be seen in different parts of the dike except that the purple muscovite occurs concentrated in seams approximately parallel to the walls of the dike as well as scattered irregularly through it.

The dikes consist essentially of light gray microcline with smaller quantities of quartz and purple muscovite. A very little albite is seen in thin sections. Only a very small quantity of other

minerals was noted and only a few kaolinized areas were seen. Thin sections of the contact do not show a sharp boundary between the dike and the quartzite and suggest that the dike is not so much a separate igneous intrusion as probably a fissure replacement effect, together with coarser recrystallization and the introduction of enough material to develop considerable microcline. The fine grained muscovite scattered through the quartzite is very similar in color to that occurring in larger scales in the dikes. "Eyes" of quartz and of muscovite, very similar in appearance, are to be found in both rocks.

The scales of the reddish purple muscovite do not reach a large size. Masses an inch thick are found in the pegmatite but individual cleavage scales seldom exceed half an inch in width. It was thought that marked differences would be found in many of the properties of the purple mica, from those of the common muscovite but the color and pleochroism show the only difference.

Both the Harding and Pilar muscovite are practically infusible before the blowpipe, with no flame coloration, when the standard test is applied. The purple color is lost, the scales becoming gray. Comparative tests with lepidolite scales of similar thickness showed a ready fusibility with the usual red flame coloration. In very thin cleavage plates, the purple muscovites slowly fuse to a grayish bead.

Examined optically, the Harding muscovite is colorless in thin sections and in thicker plates is very slightly pleochroic in shades of pink. The deeper colored mica from Pilar, however, is strikingly pleochroic, even in thin section, where basal plates are pink to yellowish. The optical orientation of the purple muscovites is normal, the axial plane being at right angles to  $b(010)$ , as determined by the position of the percussion figure.

The intensity of the pleochroism naturally varies with the thickness of the mineral. In thick cleavage scales, broken off with a knife point, the Harding muscovite is barely pleochroic in shades of pale pink; the Pilar muscovite is strongly pleochroic, from a pink or pale bluish purple ( $X$ ), to brownish orange ( $Y$ ), to a deep strawberry red ( $Z$ ). This strong pleochroism on the basal cleavage plates is most striking and is fully as strong as the pleochroism on sections normal to the base. The absorption is  $Z > Y > X$ .

A strikingly strong pleochroism on basal cleavage flakes, while abnormal for ordinary muscovite, seems to be a not unusual feature

OPTICAL PROPERTIES OF PURPLE MUSCOVITE FROM NEW MEXICO

	Harding mine.	Pilar.	Normal muscovite.
Pleochroism in thin section	{ X } { Y } { Z } } Almost none	Pale pink Yellowish Pink	{ None
Indices	$\alpha$ 1.558	1.565	1.561
	$\beta$ 1.587	1.597	1.590
	$\gamma$ 1.591	1.602	1.594
2E	69° (Meas.)	77° (Meas.)	66°
Dispersion	$\rho > \nu$	$\rho > \nu$	$\rho > \nu$

For the determination of indices and axial angles, the writers are greatly indebted to Dr. Clarence S. Ross.

for muscovite which chemically contains a strongly chromatic oxide, replacing in part the colorless alumina of normally pure muscovite. The pleochroism of fuchsite, for example, is given as: X = pale greenish blue, Y = yellowish green, Z = dark bluish green. The deep green fuchsite from near Etchison, Maryland, is reported (Dana, System of Mineralogy, p. 617) to be strongly pleochroic with X = robin's egg blue, Y = yellowish green, Z = bluish chrome-green, which colors were verified on material collected from that locality.

The density of the muscovite from the Harding mine is 2.83 and that from Pilar somewhat richer in iron, is 2.85. These determinations were made in Thoulet solution.

The samples were broken from the rock matrix by using a dental pick and each small booklet of muscovite was then cleaved until both surfaces were clean and shiny. Several grams of material were prepared in this manner and then each piece was examined individually, first under a binocular and then under a microscope. The muscovite from the Harding mine was very easy to purify as the booklets were, generally speaking, free from any inclusions. Small straight cracks were present in some of the booklets of Pilar muscovite.

The analyses of the pure muscovite from New Mexico are shown below, with two analyses of pink muscovites (from Massachusetts and California) taken from the literature, and the figures for the calculated theoretical composition of pure muscovite.

In chemical composition there is very little variation in these micas from that of normal muscovite. Small quantities of iron and

## ANALYSES OF PURPLE MUSCOVITE FROM NORTHERN NEW MEXICO.

[E. P. Henderson, analyst].

	Harding mine, N. M.	Pilar, N. M.	Goshen, <sup>1</sup> Mass.	Mesa Grande <sup>2</sup> Calif.	Theoretical
SiO <sub>2</sub>	44.80	45.16	47.02	45.63	45.2
Al <sub>2</sub> O <sub>3</sub>	37.72	35.61	36.83	37.42	38.5
Fe <sub>2</sub> O <sub>3</sub>	0.67	2.95	0.51	Trace	—
Mn <sub>2</sub> O <sub>3</sub>	0.21	0.70	—	—	—
FeO	n.d.	None	—	—	—
MnO	—	—	1.05	0.06	—
MgO	None	None	0.26	—	—
K <sub>2</sub> O	10.66	10.32	9.80	9.95	11.8
Na <sub>2</sub> O	1.40	1.03	} 0.30	1.43	—
Li <sub>2</sub> O	Trace	None		0.20	—
H <sub>2</sub> O	4.52	4.36	3.90	4.43	4.5
F	0.20	0.05	0.52	0.77	—
	100.18	100.18	100.19	99.89	100.0
O. correction	.08	.02	.22	.32	
	100.10	100.16	99.97	99.57	

<sup>1</sup> Taken from Dana's System of Mineralogy, 6th ed., p. 618, analysis No. 8.<sup>2</sup> Taken from *U. S. Geol. Survey Bull.* 591, p. 330, analysis.

manganese are present as inherent parts of the mineral, probably replacing alumina, and their combined color effect produces the abnormal color and pleochroism of the mineral.

All the manganese is reported as Mn<sub>2</sub>O<sub>3</sub>. Caesium and rubidium were looked for but could not be detected by a small laboratory spectroscope. Lithium occurs in the Harding muscovite but it is estimated to be present only in spectroscopic traces and no quantitative determination was made. The ratio of Fe<sub>2</sub>O<sub>3</sub> to Mn<sub>2</sub>O<sub>3</sub> in the Harding mica is about 3:1 and in the Pilar mica about 4:1. The ratio of combined iron and manganese oxides in the two micas is about 1:4.

The ratios of the analyses give the normal muscovite formula, as is to be expected from a comparison of the analyses. For the Harding muscovite, the ratios of SiO<sub>2</sub>:R<sub>2</sub>O<sub>3</sub>:Alk<sub>2</sub>O:H<sub>2</sub>O are 5.91:2.98:1.08:2.04: and for the Pilar muscovite they are 6.03:2.99:1.02:1.96, which ratios are very close to 6:3:1:2.



For the Pilar mica, the ratio of  $\text{Fe}_2\text{O}_3 + \text{Mn}_2\text{O}_3 : \text{Al}_2\text{O}_3$  is 1:15. Several analyses of muscovites with about this ratio of iron to alumina, and even with slightly more iron, are given by Kunitz.<sup>1</sup> The relationship he establishes for the densities of different muscovites according to their iron content is verified by the determinations of the micas from New Mexico. It was found, however, that the axial angle increases with an increase of iron content.

It is of considerable interest to see if there is any muscovite considerably richer in iron than those from New Mexico or those analyzed by Kunitz. A search of the literature revealed only one published description of a muscovite which seemed to have such a composition. This is the variety described in 1898 by Hoffmann<sup>2</sup> and named baddeckite. This mineral was found as minute scales in a plastic clay near Baddeck, Victoria County, Nova Scotia. Associated minerals are given as kaolinite (in crystalline scales), quartz, pyrite, and calcite. The copper-red baddeckite, according to Hoffmann, forms a highly plastic mass with water.

The density is given as 3.252, the fusibility as about 4.5 (to a shiny black slag), and the mineral is said to be decomposed by strong hydrochloric acid with the separation of slimy silica. The analysis was made upon "very carefully prepared and apparently perfectly pure material," though the means of purification are not stated.

A sample of baddeckite was received through the kindness of Professor T. L. Walker of Toronto. It has the properties and association ascribed to the original mineral and there seems to be no reason to question the identity of the material with the original baddeckite. The general appearance of the minute scales of the copper-red material at once suggests hematite, and such further examination of the material as was made, does not sustain the view that baddeckite is a muscovite, very high in ferric iron content.

Several attempts to separate in a pure state any of the red mineral from the clay gangue were unsuccessful. The minute scales, even in the concentrated layers, seem to have considerable clay admixed with them. Optical examination showed that the

<sup>1</sup> Kunitz, W., The relationships between the chemical composition and the physical-optical properties of the mica group: *Neues Jahrb. Min., etc.*, Beil. Band, 50, pp. 365-413 (1924).

<sup>2</sup> Hoffmann, G. Chr., Annual Rep. Geol. Survey Canada (for 1896), Vol. 9, p. 11R (1898), and (the same article) *Am. J. Sci.*, 4 ser., Vol. 6, p. 274 (1898).

red mineral formed minute sharply bounded hexagonal plates of shades of red identical with the colors of thin hematite crystals of varying thickness.

The flat lying plates were nonpleochroic and isotropic and yielded a uniaxial interference figure, the sign of which could not be conclusively determined. The refractive index of the plates was much higher than 1.74. As the New Mexico muscovite, with a ferric iron content of nearly 3 per cent, is strongly pleochroic, it would be expected that a muscovite with 25 per cent of  $\text{Fe}_2\text{O}_3$  would likewise be strongly pleochroic and show a marked differential absorption, as most high ferric iron silicates do. Moreover, a ferric iron silicate with so high a content of iron, would not be expected to be red but rather either black or green or some intermediate shade. A careful consideration of the properties of baddeckite therefore throws considerable doubt as to its being an iron rich mica.

As the general appearance of baddeckite and especially its optical properties suggest hematite and not an iron rich muscovite, it must be considered whether or not the chemical analysis given can be interpreted in such a way. The clay gangue is optically birefracting and has the general appearance and properties of those clay minerals which in late years have been classified as leverrierite. This clay matrix of the baddeckite carries a little quartz and numerous very fine rods of a yellowish mineral, probably rutile. A little calcite is present and pyrite has been reported.

A determination of the water content of the clay gangue, practically free from any baddeckite, as determined by loss on ignition, gave the following results (determinations made by W. T. Schaller):

LOSS OF CLAY GANGUE

Loss at 110°	=	0.97 per cent
Loss at 185°	=	0.58 per cent
Loss on ignition	=	4.78 per cent
Total loss	=	6.33 per cent

These values of total loss are probably in excess of the true water content as they are not corrected for the losses caused by calcite and pyrite. The water content of the clay gangue, then, is close to the percentage of water given in the analysis of baddeckite.

This water content, especially that given off at a low temperature, is unusually small for any clay mineral. It is, however, very close to the water content, given off above 100°, by the minerals of the leverrierite group, as tabulated by Larsen and Wherry,<sup>3</sup> these values for the percentages of H<sub>2</sub>O+ ranging from 5.6 to 8.65 per cent. A sample of the clay gangue, kept in a desiccator over dilute sulphuric acid of density 1.105, for a week, increased only 3.46 per cent in weight and this was readily lost again by overnight exposure in the balance case. The analysis of baddeckite, as given, can be treated as showing the composition of a mixture of a clay mineral and hematite and if all the Fe<sub>2</sub>O<sub>3</sub> reported be considered as such and the remainder of the analysis be reduced to 100 per cent, the figures obtained are not far from those reported for the clay mineral cimolite. The analysis of baddeckite is given below with its present interpretation, the remainder, after deducting the hematite, being recalculated to 100 per cent and compared with an analysis of cimolite.

ANALYSIS OF BADDECKITE INTERPRETED AS A MIXTURE  
OF HEMATITE AND CIMOLITE

	Analysis.	Hematite.	Remainder re- calculated to 100 per cent.	Cimolite, Norway, Maine.
Fe <sub>2</sub> O <sub>3</sub>	25.82	25.82	—	—
SiO <sub>2</sub>	48.96	—	66.07	66.86
Al <sub>2</sub> O <sub>3</sub>	13.85	—	18.69	22.23
CaO	1.17	—	1.58	a 1.47
MgO	2.65	—	3.58	
K <sub>2</sub> O	3.47	—	4.68	b 0.99
Na <sub>2</sub> O	0.22	—	0.30	—
H <sub>2</sub> O	3.78	—	5.10	8.26
	99.92		100.00	99.81

<sup>a</sup> Iron, manganese, lime, and magnesia.

<sup>b</sup> Alkalies and 0.06 per cent fluorine.

The comparison is close enough to suggest the possible correctness of the interpretation. No information is given by Hoffmann as to the method used in his separation of the baddeckite from the

<sup>3</sup> Larsen, E. S., and Wherry, E. T., Leverrierite from Colorado: *Jour. Wash. Acad. Sci.*, Vol. 7 (No. 8), p. 213 (1917).

clay gangue; if Thoulet solution was used, then the clay may well have extracted and retained potassium from the heavy solution.

Microscopic examination of baddeckite and brown micaceous hematite, placed side by side on a slide, showed no difference in appearance. Micaceous hematite scales, rubbed on the clay gangue, could not be told by appearance from baddeckite.

Although the conclusion that baddeckite is hematite and that the analysis was made on a mixture of hematite and a clay similar to cimolite, can not be considered to be definitely established, yet the evidence seems to be so suggestive that its possible correctness must be considered. In that case, there is no muscovite unusually rich in ferric iron, replacing the alumina, and the reddish purple muscovite from Pilar, New Mexico, must be placed with those muscovites having a maximum iron content.

#### MINERALOGY OF THE CHROME ORE FROM ETCHISON, MONTGOMERY CO., MD.

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An old chromite mine near Etchison in Maryland has been mentioned by Gill<sup>2</sup> as a locality for chrome tourmaline and fuchsite and the present writer has recently described a green margarite from this region.<sup>3</sup> The mine now consists of a shallow depression surrounded by dumps, somewhat overgrown with briars. The only rock exposed in place is a mass of rusty talc in the pit. Beneath this talc outcrop is an old tunnel which still shows a narrow opening but, since no light was available, this was not explored.

The rocks on the dump are principally made up of a grayish, somewhat schistose material which is probably largely composed of talc and chlorite. One of the puzzling features encountered at the mine was the absence of anything which could be recognized as chromite, chrome ore being supposed to exist in large quantity here. Specimens were collected from what appeared to be an ore

<sup>1</sup> Published by permission of the Secretary of the Smithsonian Institution.

<sup>2</sup> A. C. Gill. Note on some minerals from the chrome pits of Montgomery County, Maryland. *Johns-Hopkins Univ. Circular*, Vol. 8, No. 75, pp. 100-101 (1889).

<sup>3</sup> Earl V. Shannon. Chromium-colored margarite from Montgomery County, Maryland. *Amer. Mineralogist*, Vol. 9, pp. 194-195 (1924).