TRIPLITE CRYSTALS FROM COLORADO[1]

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ABSTRACT

The first measurable triplite crystals to be recorded were found in the Mica Lode pegmatite, Eight Mile Park, Fremont County, Colorado. Two other new triplite localities are the School Section pegmatite in the same district and another pegmatite in El Paso County, Colorado. The triplite occurs in hydrothermal replacement units along the footwall sides of core pods. On the basis of crystallographic measurements of four crystals and x-ray examination of an oriented section, triplite is monoclinic, prismatic $-2/m(?)$, with $a_0=11.90$, $b_0=6.48$, $c_0=9.92$, $\beta=105°53'$. The space group is $I\ 2/m$? The optical properties and specific gravity of the Mica Lode material correspond closely with those of triplite from the 7U7 Ranch, Arizona, and it is believed that the chemical composition is also similar.

INTRODUCTION

While engaged in a study of the pegmatite deposits of Eight Mile Park, Fremont County, Colorado, the junior author obtained a number of large, rudely faced crystals of triplite. The crystallography and x-ray structure of these crystals were studied subsequently by the senior author in the Mineralogical Laboratory of Harvard University. In view of the fact that the material represents the first recorded find of triplite, crystallized sufficiently well for measurement, it is believed that a detailed description is warranted. The senior author has made all the crystallographic and x-ray measurements and calculations. Geologic and paragenetic information has been supplied by the junior author. Responsibility for other parts of the paper is assumed jointly. Thanks are due to the late Dr. Charles Tozier of the Committee on Visual Education of Harvard University for the photograph of the triplite crystals.

GENERAL GEOLOGY

The geology of the Eight Mile Park pegmatite area has been studied by the junior author (Heinrich, 1947). The area is a 25-square mile plateau roughly bisected by the Royal Gorge of the Arkansas River. It is underlain by pre-Cambrian rocks of three main types: (1) Pikes Peak granite, (2) Idaho Springs schist, and (3) injection gneiss formed by lit-par-lit intrusion of schist by granitic material. The northwestern unit is granite which is bounded on the southeast by a narrow northeast-trend-

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ing belt of Idaho Springs schist. The southeastern part of the area is underlain by injection gneiss.

Moderately to steeply dipping pegmatite sills and concordant lenses are locally abundant in the Idaho Springs formation near the contacts with the Pikes Peak batholith. They attain a maximum length of 3000 feet and a thickness of 800 feet. Within the granite, also near the margins of the batholith, occur large, flat-lying, discoidal bodies of pegmatite

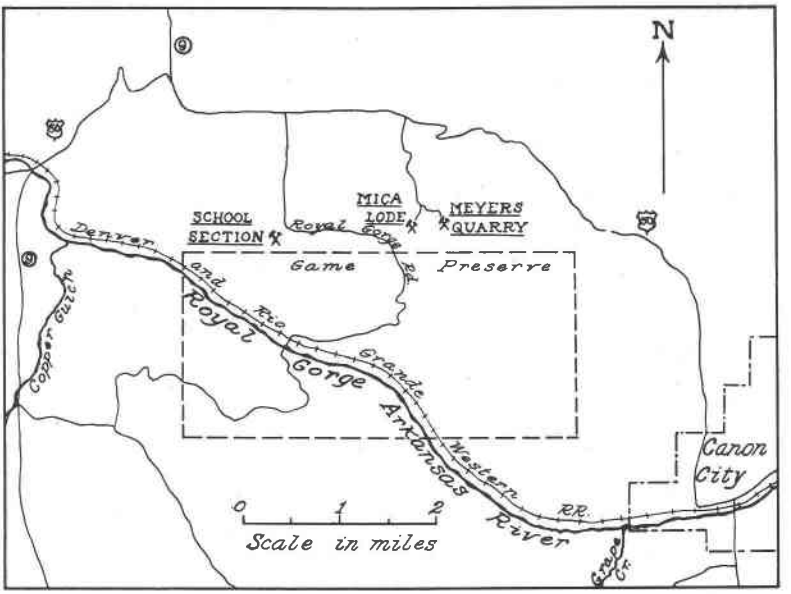

FIG. 1. Index map showing location of Mica Lode and School Section pegmatite deposits, Eight Mile Park, Fremont County, Colorado.

that transect the primary igneous foliation. Two of the three larger pegmatite deposits, the Meyers Quarry body and the Mica Lode, are in schist, and the third, the School Section deposit, occurs in granite. Triplite was found in the Mica Lode and School Section pegmatites. The location of these deposits is shown in Fig. 1. The Mica Lode is in the NE $\frac{1}{4}$, SW. $\frac{1}{4}$, sec. 14, T. 18S., R. 71 W. and the School Section quarry is in the southeast corner of Sec. 16, T. 18 S., R. 71 W.

OCCURRENCE

Triplite in rounded, anhedral masses as much as six inches in length is abundant locally in the School Section pegmatite, but no crystals were

obtained from this deposit. Associated minerals are muscovite, plagioclase, black tourmaline, and beryl. The plagioclase is of two types: pink oligoclase-albite and white cleavelandite. These minerals are concentrated in units of restricted size which underlie flat-lying to horizontal core pods. The core pods, or central zones within the pegmatite, are composed of massive white quartz and crystals of pink microcline as much as six feet across. The zonal structure appears to have formed by direct crystallization from the pegmatite magma. The triplite-bearing units, which are clearly secondary, probably formed by hydrothermal replacement of parts of the cores and parts of the adjoining graphic granite-quartz-muscovite zone.

The geologic relations at the Mica Lode are similar, except that the microcline-rich core is a single large unit that dips steeply northwest in conformity with the general attitude of the pegmatite. The footwall half of the core has been extensively replaced by abundant pink oligoclase-albite and muscovite. Beryl, with which the triplite is associated, is abundant locally in this replacement unit. Triplite pods as much as two feet long were observed in place, and about 10 tons of the material has been hand-cobbed and stockpiled. The crystals studied were obtained from the stockpile.

Some nodules of triplite are corroded and veined by albite and muscovite. At the School Section deposit veins of black tourmaline transect the phosphate. In this respect the material is similar to that found at Chatham, Connecticut. This occurrence has been described by Shannon (1921) who states (p. 445), "Intergrown intimately with the triplite are muscovite and fine-grained deep-blue tourmaline, the last surrounding the triplite in a crust and penetrating it along cracks . . . ."

In 1945 Dr. Chalmer J. Roy of Louisiana State University sent to the Mineralogical Laboratory of Harvard University a specimen of triplite from El Paso County, Colorado. According to Dr. Roy the mineral occurs in a pegmatite in the southeast corner of sec. 9, T. 16 S., R. 67 W., where it is associated with quartz, microcline, and muscovite.

Occurrence of Triplite in the United States

Data on the occurrences of triplite in the United States are summarized in Table 1.

Crystallography

Four crystals from the Mica Lode pegmatite were examined and measured by means of the contact goniometer. The two large ones, shown in Figs. 2 and 3, proved very satisfactory for contact measurement purposes and yielded moderately reproducible results. The dimensions

TABLE 1. TRIPLITE OCCURRENCES IN THE UNITED STATES

No.	Locality	Reference	Occurrence	Probable Origin
1	Stoneham, Maine	Kunz, 1884	pegmatite	hydrothermal replacement
2	Auburn, Maine	Bastin, 1911	pegmatite	hydrothermal replacement
3	Chatham, Conn.	Shannon, 1921	pegmatite	hydrothermal replacement
4	Branchville, Conn.	Dana, 1892	pegmatite	hydrothermal replacement?
5	School Section, Fremont County, Colo.	Wolfe and Heinrich, 1947	pegmatite	hydrothermal replacement
6	Mica Lode, Fremont County, Colo.	Wolfe and Heinrich, 1947	pegmatite	hydrothermal replacement
7	El Paso County, Colo.	Wolfe and Heinrich, 1947	pegmatite	?
8	7U7 Ranch, Arizona	Hurlbut, 1936	pegmatite	?; described as a segregation
9	Mt. Loma and two nearby localities, Arizona	Hurlbut, 1936	pegmatite	?; described as segregations
10	White Pine Co., Nevada	Hess and Hunt, 1913	high temperature vein	hydrothermal deposition

of these two crystals, measured in the directions of the *a*, *b*, and *c* axes, are 9×9×12 cm. and 9×12×9 cm. The other two crystals, which are less well developed, have maximum dimensions of 9 cm. The quality of the angular readings on the smaller crystals is inferior to that for the larger ones.

Quality of measurements and important measured and calculated values for the four crystals are given in Table 2. No elements have been derived from these measurements, because it is believed that the elements derived from *x*-ray values are more satisfactory. The correlation with the structural cell was accurately determined by cutting an oriented fragment from crystal 1, from which rotation and weissenberg data were obtained.

With the elements derived from an x-ray examination of an oriented crystal fragment, the following angle table (Table 3) was prepared. All of the forms listed may be considered certain. Although {112} was observed but once, it was clearly found and in good position.

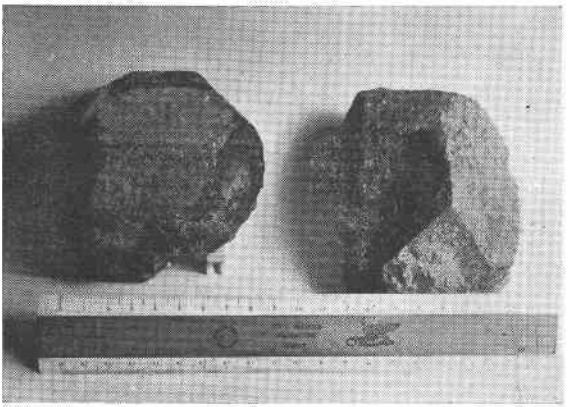

FIG. 2. Photograph of triplite crystals (crystals 1 and 2), from the Mica Lode pegmatite, Eight Mile Park, Fremont County, Colorado.

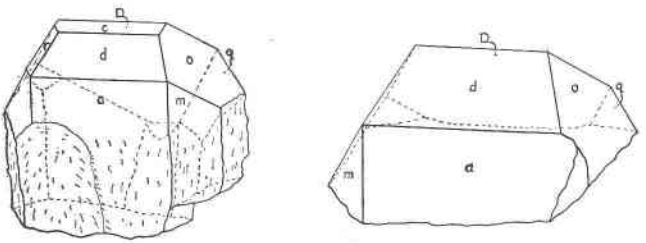

FIG. 3. Crystals of triplite from the Mica Lode pegmatite; left—crystal 1, right—crystal 2.

It is interesting to note that all of the observed forms have indices that conform to the body-centering criteria of $h+k+l=2n$, and the relative importance of the forms is in simple relationship to the spacing of the planes in the centered lattice.

Full development of a prismatic form was not observed. The crystal class is not certain; but, since a plane of symmetry was apparent on crystals 1 and 2, the class must be domatic $-m$ or prismatic $-2/m$. The latter is assumed here for lack of evidence to the contrary.

TABLE 2. SUMMARY OF CRYSTALLOGRAPHIC DATA

Measured		Calculated	
Crystal 1 (see Fig. 3) Faces observed: 001, 100, $\bar{1}00$, 110, $1\bar{1}0$, 011, $0\bar{1}1$, 101, $\bar{1}01$, $1\bar{1}2$, $\bar{2}11$, $2\bar{1}1$			
$001 \wedge 011 = 58°$	good	55°49′	
$100 \wedge 110 = 63°$	poor	60°28½′	{001} cleavage, fair
$100 \wedge 101 = 45°$	poor	40°57½′	{100} cleavage, poor
$101 \wedge \bar{1}01 = 79°$	good	79°14½′	
$\bar{1}01 \wedge \bar{2}11 = 47°$	fair	46°45′	
$011 \wedge 1\bar{1}2 = 29°$	poor	27°42′	
Crystal 2 (see Fig. 3) Faces observed: 100, $1\bar{1}0$, 011, $0\bar{1}1$, 101, $\bar{1}01$, $2\bar{1}1$			
$001 \wedge 011 = 57°$	poor	55°49′	
$100 \wedge 110 = 63°$	good	60°28½′	
$100 \wedge 101 = 41\frac{1}{2}°$	good	40°57½′	{001} cleavage, fair
$101 \wedge \bar{1}01 = 82°$	fair	79°14½′	
$\bar{1}01 \wedge \bar{2}11 = 49\frac{1}{2}°$	good	46°45′	
Crystal 3 (not figured) Faces observed: 001, 100, $\bar{1}00$, 011			
$101 \wedge \bar{1}01 = 78°$	fair	79°14½′	
Crystal 4 (not figured) Faces observed: $\bar{1}00$, $\bar{1}01$, $\bar{2}11$			
$\bar{1}00 \wedge \bar{1}01 = 62°$	fair	59°48′	{001} cleavage, good
$\bar{1}01 \wedge \bar{2}11 = 44\frac{1}{2}°$	poor	46°45′	{010} cleavage, fair

TABLE 3. TRIPLITE—ANGLE TABLE

Monoclinic: Prismatic $-2/m$ (?)

$a:b:c = 1.836:1:1.531$; $\beta = 105°53'$; $p_0:q_0:r_0 = 0.834:1.472:1$

$r_2:p_2:q_2 = 0.679:0.566:1$; $\mu = 74°07'$; p_0' 0.867, q_0' 1.531, x_0' 0.285

Forms:	ϕ	ρ	ϕ_2	$\rho_2 = B$	C	A
c 001	90°00′	15°53′	74°07′	90°00′	0°00′	74°07′
a 100	90 00	90 00	0 00	90 00	74 07	0 00
m 110	29 31½	90 00	0 00	29 31½	82 15	60 28½
o 011	10 32½	57 17½	74 07	34 11	55 49	81 08½
d 101	90 00	49 02½	40 57½	90 00	33 09½	40 57½
D $\bar{1}01$	−90 00	30 12	120 12	90 00	46 05	120 12
r 112	43 11	46 23½	54 18	58 08	36 58	60 17½
q $\bar{2}11$	−43 25½	64 37½	145 23½	48 59½	75 59	128 23½

X-ray Data

In order to correlate the geometrical crystallography with the *x*-ray data of Richmond (1940) an oriented section was cut from crystal 1, and rotation, 0-layer line, and 1-layer line pictures were taken about the [010] axis, with copper radiation. The solution of these pictures gave the following results:

	Wolfe-Heinrich	Richmond
Space Group	$I\,2/m$	$P\,2_1/a$
a_0	11.90	12.03
b_0	6.48	6.46
c_0	9.92	10.03
β	105°53′	105°42′
Measured gravity	3.64	3.84
Calculated gravity	3.64	3.94
Mg:Mn:Fe=	2:3:1	Fe:Mn=1:8

Richmond's original pictures were reexamined, and the space group is definitely body-centered.

Optical Properties

The optical properties of the Mica Lode triplite are as follows:

Orientation	*n*	*Pleochroism*
$X \wedge a = 57°$	$1.643 \pm .003$	reddish brown
$Y = b$	1.647	yellow
$Z \wedge c = -41°$	1.668	reddish brown

(+); 2V=25° (measured); $r > v$, moderate

Table 4 compares the optical properties of the Colorado triplites.

Table 4. Optical Properties of Colorado Triplites

	School Section	Mica Lode	El Paso County
*n*X	$1.671 \pm .003$	$1.643 \pm .003$	$1.648 \pm .003$
*n*Y	1.681	1.647	1.652
*n*Z	1.686	1.668	1.672
2V	moderate	40°	55°
Sign	(−)	(+)	(+)

Chemical Composition

The optical properties of the Mica Lode triplite are comparable to those determined by Hurlbut (1936) for the mineral from the 7U7

Ranch, which contains nearly 12% MgO and has an Mg:Mn:Fe ratio of 2:3:1. The specific gravity for triplite of that composition as calculated with our *x*-ray data is 3.64. Several gravity determinations, made by means of the Berman balance on pure fragments of the Mica Lode triplite, gave an average value of 3.64. A qualitative test indicated the presence of relatively large amounts of magnesium in this triplite.

Complete analyses of both the Mica Lode and the School Section triplites are to be made in the future. It is certain, however, that triplite can no longer be regarded as a simple series between Fe″ and Mn, as indicated by Otto (1936) and Richmond (1940). In some triplites magnesium enters into the composition in important quantities; and, as Hurlbut (1936, p. 656) noted, the optical and other physical properties clearly reflect this variation.

Alteration

Triplite is commonly altered to black manganese oxide which coats the crystals and stains the surrounding minerals. Most of the triplite crystals and pods also are enclosed in a thin shell of altered material which lacks the usual vitreous luster and is also somewhat darker in color. This outer skin has been variously described as "pseudotriplite" or a "substance near heterosite" (*Dana*, 1892).

The material of the outer shell has an *nZ* index of refraction considerably lower than that of triplite (in the Mica Lode mineral, 1.600 as compared to 1.668), but *x*-ray powder photographs of the shell and the fresh triplite core are identical. The shell probably represents the initial stage in the breakdown of the triplite. The isostructural decomposition product may be the result of partial oxidation of the iron and manganese. Under the microscope the outer material is nearly opaque owing to the presence of very abundant minute dark brown inclusions.

References

1. Bastin, E. S. (1911), Geology of the pegmatites and associated rocks of Maine: *U. S. Geol. Survey, Bull.* **445,** 18.
2. Dana, E. S. (1892), *System of Mineralogy*, 6th ed. New York, p. 778.
3. Heinrich, E. Wm. (1947), Geology of the Eight Mile Park pegmatite area, Colorado: Unpubl. Ph.D. thesis, Harvard University.
4. Hess, Frank L., and Hunt, W. F. (1913), Triplite from eastern Nevada: *Am. Jour. Sci.*, **36,** 51–54.
5. Hurlbut, Cornelius S., Jr. (1936), A new phosphate, bermanite, occurring with triplite in Arizona: *Am. Mineral.*, **21,** 656–661.
6. Kunz, George F. (1884), Topaz and associated minerals at Stoneham, Me.: *Am. Jour. Sci.*, **27,** 212–216.
7. Otto, Helmut (1936), Die Rolle des Mangans in den Mineralien: *Min. Mitt.*, **47,** 89–140.

8. RICHMOND, WALLACE E. (1940), Crystal chemistry of the phosphates, arsenates and vanadates of the type $A_2XO_4(Z)$: *Am. Mineral.*, **25,** 441–479.
9. SHANNON, EARL V. (1921), Notes on anglesite, anthophyllite, calcite, datolite, sillimanite, stilpnomelane, tetrahedrite and triplite: *Proc. U. S. Nat. Mus.*, **58,** 437–453.
10. SHEPARD, CHARLES W. (1852), On the triplite (alluandite?) of Norwich, Massachusetts: *Am. As. Pr.*, **6,** 234–235.