# A NEW PHOSPHATE, BERMANITE, OCCURRING WITH TRIPLITE IN ARIZONA

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In 1929, R. M. Wilke sent to the Department of Mineralogy at Harvard University a suite of mineral specimens collected near the Bagdad Copper Mine, about 25 miles west of Hillside, Arizona. In 1931 the writer visited the locality and several others nearby, and made a more complete collection.

## TRIPLITE

The original material came from a nearly spherical segregation about two feet in diameter within a pegmatite knot located on the 7 U 7 Ranch. The pegmatite is lens shaped, about 20 feet in maximum dimension, and composed dominantly of milky quartz with some orthoclase and muscovite. It appears to be completely inclosed within a coarse-grained granite. Triplite makes up the bulk of the segregation, but along fractures in it secondary minerals have been deposited. Considering its limited volume, the triplite is coarsely crystalline with single cleavage fragments measuring as much as six inches across. Only small amounts are fresh with a pinkish brown color and resinous luster, and much of it is a shiny black due to oxidation of the manganese.

At three other locations, all within a radius of seven miles, triplite was found as the chief constituent of similar segregations within pegmatite knots. The largest pegmatite forms a hill about 100 feet in diameter and 50 feet high. Triplite was found here in a small pocket near the top of the hill associated with a green mica and fluorite. At the two remaining localities, one at the base of Mt. Loma and the other in "the granites," triplite was the only mineral found in addition to the ordinary pegmatite minerals. The optical properties showed the triplite from these three localities to be the same, but different from that at the 7 U 7 Ranch. Accordingly, chemical analyses were made of triplite from the 7 U 7 Ranch and from Mt. Loma.

The triplite from Mt. Loma has a ratio of Fe:Mn = 1:8 and is thus similar to that from Branchville, Conn., as given in Dana.[1] That from the 7 U 7 Ranch differs from any hitherto reported, with a ratio of Fe:Mn:Mg = 1:3:2. The optical properties reflect this difference, and show not only lower indices of refraction, but a wholly different optical orientation.

[1] Dana, E. S., *System of Mineralogy*, 6th ed., New York, **1892.**

ANALYSES OF TRIPLITE BY F. A. GONYER

| | I | II |
|---|---|---|
| $Fe_2O_3$ | — | 0.40 |
| FeO | 11.68 | 6.68 |
| MnO | 34.55 | 53.77 |
| MgO | 11.87 | 0.31 |
| CaO | 2.48 | 2.17 |
| $Na_2O$ | 0.52 | — |
| $H_2O$ | 0.75 | — |
| $P_2O_5$ | 33.32 | 32.20 |
| F | 8.02 | 7.58 |
| | 103.19 | 103.11 |
| Less 0 | 3.38 | 3.19 |
| | 99.81 | 99.92 |

I. Triplite from the 7 U 7 Rranch
II. Triplite from Mt. Loma

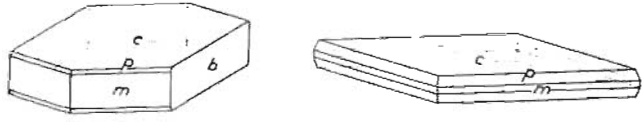
OPTICAL PROPERTIES OF ARIZONA TRIPLITE

| I | II |
|---|---|
| $\alpha=1.651$ Opt. (+) | $\alpha=1.662$ Opt. (−) |
| $\beta=1.653$ $2V=28°$ | $\beta=1.673$ $2V=88°$ |
| $\gamma=1.665$ $r>v$ str. | $\gamma=1.684$ $r>v$ |
| $X=b$ $Z\wedge a=22°$ | $Y=b$ $Z\wedge a=42°$ |

I. Triplite from the 7 U 7 Ranch
II. Triplite from Mt. Loma

## BERMANITE

In narrow veinlets crossing the triplite at the 7 U 7 Ranch is a reddish brown mineral that is found in small crystals where the veins open into narrow vugs. This proved to be a new species and is called bermanite. In addition to the bermanite, six other minerals are present on the walls of the cavities, of which only one, torbernite, in small green pseudocubes, could be identified. Four of the minerals are present as tiny bril-




1 2

FIGS. 1 and 2. Bermanite.

liantly colored crystals in amounts barely sufficient to determine their optical properties, while the remaining one forms in thin white crusts.

Bermanite is orthorhombic with a pronounced tabular habit. The largest crystals are several millimeters across, and most of them are arranged in subparallel aggregates with a fan-shaped or rosette-like appearance. Figure 1 shows the characteristic form of the larger crystals

with the base, prism and brachypinacoid dominant. Only crystals under 0.5 mm. in maximum dimension proved to be single individuals, and consequently goniometric measurements were confined to crystals below that size. These smaller crystals differ from the larger ones in habit; (010) is rarely present, and (111) is a prominent form as shown in Fig. 2.

TABLE 1

BERMANITE. TWO-CIRCLE MEASUREMENTS ON TEN CRYSTALS

| Forms | Faces | Measured Range | | Measured Mean | | Calculated | |
|---|---|---|---|---|---|---|---|
| | | $\phi$ | $\rho$ | $\phi$ | $\rho$ | $\phi$ | $\rho$ |
| $c$(001) | 10 | | | — | 0°00′ | — | 0°00′ |
| $b$(010) | 4 | 0°01′– 0°13′ | 89°56′–90°05′ | 0°06′ | 90 00 | 0°00′ | 90 00 |
| $m$(110) | 10 | 55°20′–55°31′ | 89 50 –90 05 | 55 27 | 89 59 | 55 26 | 90 00 |
| $r$(116) | 3 | 55 28 –55 36 | 32 20 –32 23 | 55 31 | 32 22 | 55 26 | 32 53½ |
| $n$(113) | 7 | 54 58 –55 45 | 51 39 –52 40 | 55 28 | 52 18 | 55 26 | 52 17½ |
| $o$(112) | 5 | 54 21 –54 36 | 62 22 –62 49 | 55 22 | 62 35 | 55 26 | 62 44 |
| $p$(111) | 24 | 54 41 –56 19 | 74 47 –75 42 | 55 25 | 75 33 | 55 26 | 75 33 |

TABLE 2

BERMANITE—$(Mn'', Mg)_5Mn_8'''(PO_4)_8(OH)_{10} \cdot 15H_2O$

Orthorhombic; dipyramidal—$2/m\ 2/m\ 2/m$

$a:b:c = 0.6890:1:2.2018$; $p_0:q_0:r_0 = 3.1956:2.2018:1$

$q_1:r_1:p_1 = 0.6890:0.3038:1$; $r_2:p_2:q_2 = 0.4542:1.4514:1$

| Forms | $\phi$ | $\rho$=C | $\phi_1$ | $\rho_1$=A | $\phi_2$ | $\rho_2$=B |
|---|---|---|---|---|---|---|
| $c$(001) | — | 0°00′ | 0°00′ | 90°00′ | 90°00′ | 90°00′ |
| $b$(010) | 0°00′ | 90 00 | 90 00 | 90 00 | — | 0 00 |
| $m$(110) | 55 26 | 90 00 | 90 00 | 34 34 | 0 00 | 55 26 |
| $r$(116) | 55 26 | 32 53½ | 20 09 | 63 26 | 61 57½ | 72 03 |
| $n$(113) | 55 26 | 52 17½ | 36 16½ | 49 21 | 43 11½ | 63 19½ |
| $o$(112) | 55 26 | 62 44 | 47 45 | 42 57 | 32 02½ | 59 43 |
| $p$(111) | 55 26 | 75 33 | 65 34½ | 37 07 | 17 22½ | 56 40½ |

Ten crystals were measured, each of which had one dominant face with the pyramid faces truncating it symmetrically. This best-developed face was taken as the basal pinacoid, thereby fixing the position of the crystallographic axes.

A reasonable agreement between the measured and calculated position angles of the various forms is shown in Table 1. The pyramid $r$ was

found only on one crystal as line faces and its measurements are consequently less satisfactory. Aside from the basal pinacoid the steep pyramid (111) is the most prominent form. The prism zone is poorly developed in the small measured crystals, with (110) present only as line faces, and (010) only as points.

*X-Ray Measurements:*—Rotation photographs were taken about the three crystallographic axes. The dimensions of the unit cell thus obtained are:

$$a_0 = 6.25\text{Å},\ b_0 = 8.92\text{Å},\ c_0 = 19.61\text{Å}$$

which give the ratio:

$$a_0 : b_0 : c_0 = 0.701 : 1 : 2.198.$$

This ratio is in fair agreement with the morphological axial ratio: $a:b:c = 0.6890:1:2.2018$.

*Physical and Optical Properties:*—The cleavage of bermanite is perfect parallel to (001), and imperfect parallel to (110). The hardness is 3.5. The specific gravity is 2.84 determined by suspension in bromoform. The color is a reddish brown, somewhat darker on exposed surfaces. The optical properties determined by the immersion method are as follows:

| | | | |
|---|---|---|---|
| X = $c$-axis | $\alpha = 1.687$ | | Negative |
| Z = $a$-axis | $\beta = 1.725$ | $\pm 0.003$ | $2V = 74°$ |
| | $\gamma = 1.748$ | | $r < v$ |

Pleochroism: X = light red, Y = pale yellow, Z = deep red.

Chemical composition: The following analysis of bermanite yields the formula: $R_5''R_8'''(PO_4)_8(OH)_{10} \cdot 15H_2O$, where

$$R''' = \text{Mn} : \text{Fe} = 9:1$$
$$R'' = \text{Mn} : \text{Mg} : (\text{Ca} + \text{Na}) = 19:6:2$$

ANALYSIS OF BERMANITE BY F. A. GONYER

| | |
|---|---|
| $Fe_2O_3$ | 3.03% |
| $Mn_2O_3$ | 28.76 |
| MnO | 13.79 |
| MgO | 2.39 |
| CaO | 0.72 |
| $Na_2O$ | 0.32 |
| $H_2O$ | 19.33 |
| $P_2O_5$ | 31.39 |
| | 99.73 |

The molecular weight of the unit cell (M) was determined by use of the formula, $M = \frac{Vd}{A}$, where $V$ is the volume of the unit cell ($1094 \times 10^{-24}$ c.c.), $d$ is the density (2.84 gm/c.c.) and $A$ is the reciprocal of Avagadro's number ($1.65 \times 10^{-24}$). The value for $M$ is 1883. The number

of atoms in the unit cell was determined by the use of $M$, and is listed below with the percentage weights of the chemical analysis reduced to 100 per cent.

| | *Per cent* | *Molecular ratio* | | *Atomic ratio* | *Atoms/ unit cell* | |
|---|---|---|---|---|---|---|
| $Fe_2O_3$ | 3.04 | 0.0190 | Fe | 0.0380 | 0.72 | 7.58 |
| $Mn_2O_3$ | 28.84 | 0.1822 | Mn | 0.3644 | 6.86 | |
| MnO | 13.82 | 0.1944 | Mn | 0.1944 | 3.66 | |
| MgO | 2.40 | 0.0593 | Mg | 0.0593 | 1.12 | 5.22 |
| CaO | 0.72 | 0.0128 | Ca | 0.0128 | 0.24 | |
| $Na_2O$ | 0.32 | 0.0052 | Na | 0.0104 | 0.20 | |
| $H_2O$ | 19.38 | 1.0730 | H | 2.1460 | 40.41 | 40.41 |
| $P_2O_5$ | 31.48 | 0.2210 | P | 0.4420 | 8.32 | 8.32 |
| | 100.00 | | | | | |

If it is assumed that the numbers in the last column represent the integers 8, 5, 40, and 8, respectively, the composition of the unit cell is:

$$R_5''R_8'''(PO_4)_8(OH)_{10}\cdot 15H_2O.$$

*Pyrognostics:*—On charcoal before the blowpipe bermanite first swells and separates into scales, and then fuses easily to a globule. With borax an amethystine bead is given in the oxidizing flame, that becomes colorless in the reducing flame. A bluish green bead is given with soda. Bermanite swells in the closed tube and yields abundant neutral water. It is soluble in nitric acid and forms a yellow precipitate with ammonium molybdate.

In view of the many contributions to the science of mineralogy by Dr. Harry Berman, it seems fitting to name this new species bermanite in his honor.

## Unidentified Phosphates

Qualitative chemical tests show all five of the unidentified minerals that occur with bermanite at the 7 U 7 Ranch to be phosphates. Inasmuch as four of them are found only in isolated crystals, it is difficult to establish a definite sequence of deposition. In the following brief description, however, they will be referred to by number in the order in which it is believed they were deposited.

Number 1 is present in bright blue grains surrounded by a lighter blue area several millimeters in diameter. Its alteration is believed to account for the staining of the surrounding cavity wall.

Number 2 is a light brown mineral, more abundant than any of the others, and frequently shows crystal outlines. An attempt to measure it on the goniometer, although not entirely successful, indicated it is orthorhombic with the forms (001), (111), and (110) present. Parallel

extinction against the cleavage faces also pointed to orthorhombic symmetry.

Number 3 is purple, and occurs in rounded grains that show an occasional crystal face.

Number 4 is a wine-colored mineral that is found in small amounts as minute tabular crystals.

Bermanite follows number 4 in the sequence of deposition, and no doubt thick crusts of it in many places obscure the earlier minerals.

Number 6 forms thin white crusts that cover the earlier minerals. It is soft and has much the appearance of gypsum.

OPTICAL PROPERTIES OF UNIDENTIFIED PHOSPHATES

| | 1 | 2 | 3 | 4 | 6 |
|---|---|---|---|---|---|
| Indices | $\alpha=1.690$<br>$\beta=1.720$<br>$\gamma=1.729$ | $\alpha=1.591$<br>$\beta=1.615$<br>$\gamma=1.639$ | $\omega=1.740$<br>$\epsilon=1.763$ | $\alpha=1.706$<br>$\beta=1.718$<br>$\gamma=1.731$ | $\alpha=1.642$<br>$\beta=1.650$<br>$\gamma=1.653$ |
| Op. char. | (−) | (−) | (+) | (−) | (−) |
| 2V. | 50° | 80° | | 65° | 70° |
| Dispersion | | $r>v$ str. | | | $r>v$ |
| Orientation | | orthorhombic<br>Z=b, X=a | | | |
| Cleavage | | (100) good<br>(010) fair | | | |
| Pleochroism | X=clear<br>Y=lt. blue<br>Z=pale pink | | O=pale blue<br>E=deep purple<br>to pink | | |

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