CRYSTALLIZED POWELLITE FROM TONOPAH, NEVADA

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Although powellite has been found at a number of localities, crystals have been reported only twice. It was originally identified and described as a new mineral by Melville,[1] who discovered it at the Seven Devils Mine in Idaho. He reported distinct crystals as much as 2.5 mm. across, although the average size was much smaller. After this determination, it was found at a number of localities, but always as a pulverulent coating, or in platy, pearly ocherous masses, pseudomorphous after molybdenite. The only other published descriptions of distinct crystals are those of the most notable occurrence to date; those of Houghton, Michigan. These were first noted by Koenig and Hubbard,[2] but more fully studied and figured by Palache,[3] who described two large and excellent crystals with several new forms.

With crystals of powellite as uncommon as this brief review shows, a suite collected at the Tonopah Divide Mine, near Tonopah, Nevada, is worthy of description. A considerable number of specimens was available for the study; in part borrowed from Harvard University through the kindness of Professor Charles Palache, and the remainder recently collected by Mr. C. D. Woodhouse, of Mocalno, California. The crystals occur in crusts, lining small vugs in an altered rhyolite and form a continuous layer of firmly intergrown individuals. The component crystals are small, averaging about 1.5 mm. in breadth, although some of the largest are as much as 5 mm. across. They differ greatly in habit and color. Some crusts show varying color tones, from a deep transparent brown, in the clearer portions of the crystals, to a milky brown on many of the surfaces where a thin skin composing the outer layer conceals the transparent interior. This skin appears to be very superficial and may be due to the presence of minute open spaces. Some crystals are half cloudy and half clear; the boundary line is abrupt and always runs vertically across the face, never parallel to the basal plane. The surfaces have an adamantine luster, but this, too, varies when the milky skin is present. The clearer crystals have brilliant faces marked by a series of striations

[1] Melville, W. H., Powellite-calcium molybdate: A new mineral species. *Am. Jour. Sci.*, (3), vol. **41**, pp. 138–141, 1891.

[2] Koenig, G. A., and Hubbard, L. L., On powellite from a new locality: *Am. Jour. Sci.*, (3), vol. **46**, pp. 356–358, 1893.

[3] Palache, C., Powellite crystals from Michigan: *Am. Jour. Sci.*, (4) vol. **7**, pp. 367–369, 1899.

running in the vertical plane across the face. The surfaces of the milky faces are much less brilliantly reflecting, show a somewhat rounded and irregular surface, and lack the distinct parallel striations.

Other crusts, however, are very different in appearance, with pale yellow-brown and almost completely transparent crystals. In some the crystals are in parallel arrangement, either in a single group or in two or three units which compose the entire crust a centimeter or more across. Others show complete random orientation of the individuals. These paler crystals are more even and brilliant, are unstriated, and show very different forms and habits from those of the type first described. Some are pyramidal, while others are thinly tabular, resembling wulfenite crystals of this habit.

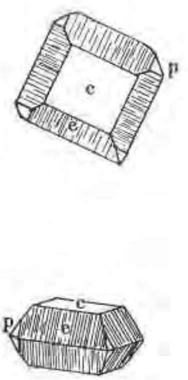

FIG. 1

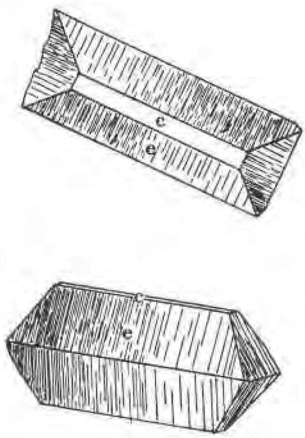

FIG. 2

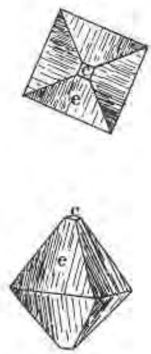

FIG. 3

The crystals forming the deep brown crusts show three variations of a pyramidal habit. The least common of these is that shown in Fig. 1, and is the usual habit of the smallest crystals, the ones about .3 mm. across. Such crystals were seen in smaller vugs or in fissures, but not on the larger and thicker crusts. The base is rather prominent, *e* is less striated than in the larger crystals and gives a good signal. The train-of-reflection is less continuous than in the other crystals and the form terminating the train, *p*, is better developed than is commonly the case. The base gives an excellent single reflection.

A more common habit is that shown in Fig. 2, which characterizes many of the larger brown crystals. The base is small and unimportant on these, which are dominated by *e*, and they are greatly distorted along an horizontal axis, so that two pairs of bipyramid faces are very much elongated in relation to the other pairs. The distribution of the striated planes makes the orientation of any of the distorted crystals very simple, however, and the forms are easily determined. As in the typical undistorted crystal shown in Fig. 3, the tetartohedry is pronounced. It reveals itself, even to casual inspection, through a rounding of the corners on the right or left sides of each *e* face, often grading into *p*. On the goniometer a continuous train-of-reflection is seen to extend from *e* through *h* and *r*, and on to *p*.

r (323) is a new form which was commonly observed on the pyramidal crystals of this group. It lies in the zone marked by the train-of-reflection and gives an intense and distinct signal in the train. *h* (313), first observed by Palache on a Michigan crystal, gives a similar signal in the train. No good forms were found between the base and the pyramids of the unit zone, although some apparent truncations were observed.

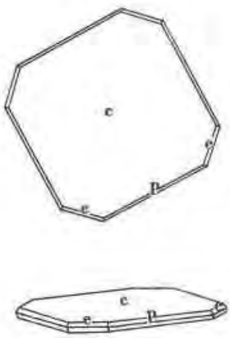

Fig. 4

They did not give good signals and cannot be considered acceptable forms.

Some new forms were found in this area, however, on some of the clearer pale-colored crystals. The crystals of this shade formed two widely divergent habit groups. One was tabular, some of the crystals paper-thin with the edges modified by *e* and *p*, the latter dominant; in marked contrast to the previously figured crystals on which *e* has been the broader form. No measurable forms lying between these and the base were observed. The faces of *e* and *p* are somewhat irregular, in the manner of wulfenite crystals of this habit, and do not give good signals. They are sufficiently good, however, for the determination of the forms. A typical crystal is shown in Fig. 4.

The most interesting of the crystals were the clear pyramidal ones, for they showed several new forms. The best developed and most perfect crystals consist of a simple combination of *c*, *e* and *p*, without other forms, but a few showed two additional very well-developed forms,

U (137) and u (317);[4] as shown in Fig. 5. The faces of these complementary forms lie at the top of e, truncating that form at its intersection with the base. They form distinct pairs of faces, occurring thus four times on an end, no tetartohedry being apparent. The measured angles were:

$\phi=18°48'$ $\phi=71°12'$ $\rho=35°05'$

Calculated:

$\phi=18°26'$ $\phi=71°34''$ $\rho=34°57'$

Between these pairs, lying a little to the side of the [cp] zone, is another form which was observed four times on the crystal and which approaches very near to (4·3·14) in its symbol. Although it seems to be a new form on the crystal, it cannot be accepted without confirmation, because of the uneven measurements secured.

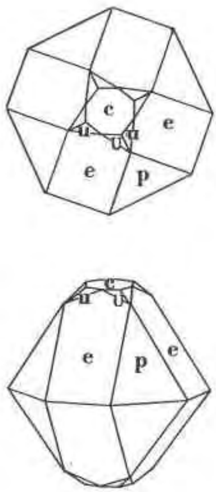

Fig. 5

Several other crystals of this type were measured and the U-u combination found on all of them. Most of these crystals were very irregularly developed, and did not form solid, regular bodies, but instead, showed uneven surfaces, on which, nevertheless, faces were regularly if unequally distributed. The crystals, and the new forms, are, for this reason, not figured, but excellent measurements were secured and four additional new forms made certain. These are: (123), (213), (319), and (113), lettered F, f, x, and b, respectively.

[4] (137) and a second new form (131), to be discussed later, were observed independently by Professor Palache in the course of some unpublished investigations

	Measured:		Calculated:	
F	$\phi=26°55'$	$\rho=49°02'$	$\phi=26°34'$	$\rho=49°04'$
f	$\phi=63°05'$	$\rho=49°02'$	$\phi=63°26'$	$\rho=49°04'$
x	$\phi=71°27'$	$\rho=27°57'$	$\phi=71°34'$	$\rho=28°32'$
b	$\phi=45°00'$	$\rho=35°46'$	$\phi=45°00'$	$\rho=36°07'$

The last form, *b*, has already been noted upon artificial crystals, but this is the first natural occurrence of the form.

It is interesting to note that the pronounced tetartohedry of the mineral does not reveal itself in the distribution of forms lying within the unit distance, with the exception of *x* and one doubtful form. In the $[\bar{1}01]$ zone, on the other hand, the tetartohedry is marked, and no complementary forms appear; a form is right or left, depending upon which end of the crystal is up. In order to avoid confusion it would be well to remember that this is the case; all of the forms in $[\bar{1}01]$ lie in a single zone and if the zone is called $[01\bar{1}]$ it makes no difference, as long as it is understood to contain all of the forms intersecting the *c*-axis at unity.

A careful measurement of the best crystals available showed that the ρ angle of the form *e* did not agree with that given for it in any of the published angle-tables. The results of thirty measurements on as many crystals were averaged to give a ρ angle for this form of 57°08'. Repeated attempts on two carefully selected very perfect crystals gave exactly the same value, so it was decided that a new axial ratio should be calculated, and new angles for the accepted forms. The following angle-table is calculated on the basis of a ratio of $a:c$ of 1:1.5477, or a p_0 of 1.5477, as are the calculated angles given in the above discussion. The angle-table is revised to include all of the accepted forms, including two, *S*(131), and *W*(153), which will be discussed later. All of the forms marked by an asterisk are new. All but *m*, *l*, *k* and *j* were observed during the course of this study.

The forms are listed according to usage and according to the increase in *p*, with a divergence from this practice in the case of complementary forms, in order to avoid a separation in the listing of forms which belong together. ϕ angles up to +90° suffice for all forms of this class; only in the case of the tetartohedral sphenoidal class will negative ϕ angles be necessary.

Note on Powellite from Houghton, Michigan

At the beginning of the preceding study, it was thought desirable for orientation purposes, to make a comparison of the appearance and reflections of the new crystals with one from the old Houghton locality. For this purpose, an excellent small crystal, attached to a quartz crystal, was removed from a specimen in the collection of the American Museum of Natural History. This crystal, a deep translucent blue one about 2 mm. across, showing touches of brown in transmitted light, gave excellent signals and a train extending from *e* to *p*, just as in the Nevada crystals described above. However, the crystal was found to be different

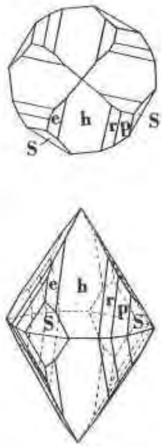

FIG. 6

from those described by Professor Palache, and to show a most unusual habit as well as two new forms. It is shown in Fig. 6. As may be seen, *e* is very narrow, but perfectly plane and brilliant, giving an excellent signal. The most prominent form, however, is *h*, which is dominant, making the crystal a little skewed from the axial directions. The signal from this form is blurred and covers several degrees in the train, the ρ angle naturally is much more exact than ϕ. A similar slightly attenuated signal next occurred in the train in the position of (323), already described on the Nevada crystals. The form is narrow, but well developed and but slightly rounded.

Measured:	*Calculated:*
$\phi=56°25'$	$\phi=56°19'$
$\rho=60\ 50$	$\rho=61\ 44$

The train ends with *p*, but further along in the same zone lies the comparatively large and very brilliant form *S* (131). This form was found six times on the crystal, three times on each end, and gave perfect signals.

Measured:	*Calculated:*
$\phi=18°27'$	$\phi=18°26'$
$\rho=78\ 23$	$\rho=78\ 27$

Because of these two new forms, as well as the unusual habit of the crystal, it was thought advisable to figure and describe this crystal as well.

POWELLITE
Angle-Table

$p_0=1.5477$ $a:c=1:1.5477$

Form	Miller	φ	ρ
c	001	—°—′	00°00′
m	110	45 00	90 00
e	011	00 00	57 08
*b**	113	45 00	36 07
p	111	45 00	65 27
*L**	137	18 26	34 57
*u**	317	71 34	34 57
*x**	319	71 34	28 32
*F**	123	26 34	49 04
*f**	213	63 26	49 04
*W**	153	11 19	69 11
l	11·1·11	84 48	57 14
k	515	78 41	57 38
j	11·3·11	74 45	58 04
h	313	71 34	58 30
*r**	323	56 19	61 44
*S**	131	18 26	78 27

NOTE ON POWELLITE FROM ISLE ROYALE MINE, HOUGHTON, MICHIGAN

C. PALACHE

A single crystal of powellite, found in a quartz vug from the Isle Royale Mine, was loaned to the writer for study by President McNair of

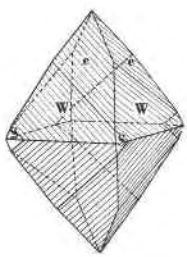

FIG. 7

the School of Mines at Houghton. This crystal was measured and the accompanying drawing made some thirty years since. The form and peculiar striations of this crystal are so unusual that it seems well to take this occasion to put the observation on record. Unfortunately, the record of the angles obtained for the new form (153) can no longer be found. The crystal shows the forms *e* (101), *W* (153) and *S* (131). The form *S* is confirmed by Dr. Pough's work. The form *W* (153) was equally well founded and its good place in the projection, in spite of the loss of the record, makes the form seem worthy of recognition. The striation, in the direction of the edge [$2\bar{1}1$], gives a highly skew appearance to the crystal.