BULTFONTEINITE FROM CRESTMORE, CALIFORNIA

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ABSTRACT

The rare mineral bultfonteinite has been found in the contact zone at Crestmore, California, in association with afwillite and scawtite. It occurs with these as microscopic, twinned individuals, much finer grained than the enclosing minerals. Optical and microchemical observations indicated that it is bultfonteinite, and this is confirmed by *x*-ray powder pattern, which matches that of the type material. This is the first locality for this mineral outside of South Africa. The powder pattern shows the following spacings and intensities for the strongest lines: 8.16 Å-7; 3.51 Å-5; 3.46 Å-5; 2.92 Å-10; 2.885 Å-10; −1.93 Å-10.

X-ray measurements on a crystal sliver from the type locality give cell-dimensions and angles as follows:

$a_0=8.34$ Å	$b_0=11.18$ Å	$c_0=5.68$ Å
$\lambda=88°\ 24'$	$\mu=86°\ 06'$	$\nu=90°\ 00'$

These agree very closely with morphological measurements by Wright, provided his *a* and *b* axes are exchanged, and the value for the new *b* axis is doubled. The transformation formula, Wright to Murdoch is 010/200/001.

The rare mineral Bultfonteinite was discovered about 1903 or 1904 in the Bultfontein mine, in the Kimberley District, South Africa. Several years later it appeared in the Dutoitspan mine in the same district, and shortly before 1932 it was found also at the Jagersfontein mine in the Orange River Colony, some hundred miles southeast of Kimberley. When first collected, it was thought to be natrolite, but was later recognized by A. F. Williams as a new mineral, and as such described by Parry, Williams, and Wright (1932). It is a hydrous, fluorine-bearing calcium silicate, close to $11Ca(OH, F)_2 \cdot 5SiO_2$ in composition, and quite similar in many properties to afwillite. The new mineral was originally called dutoitspanite, Williams (1932, p. 171), but later changed to bultfonteinite.

On examining some specimens of massive afwillite, and later also of scawtite, from the 910′ level of the Commercial quarry at Crestmore, California, the writer observed some patches and stringers of a fine-grained, sugary-textured material in the coarser matrix. This suggested a different mineral, and microscopic examination showed these areas to be composed of a granular aggregate of stout prismatic grains showing multiple twinning like that of a plagioclase. Selected material showed them to be biaxial positive with 2V near 70° and with a beta index close to 1.59. Grains with sharply defined twin lamellae showed a symmetrical extinction angle of 27–28°. Microchemical tests gave CaO, SiO_2, H_2O and F. Leaching with water produced an alkaline solution. These properties correspond with those of bultfonteinite, which is easily dis-

tinguished from the optically similar custerite by the extinction angle, which in the latter is only about 6° (Tilley 1928), and from afwillite which does not have multiple twinning. Incidentally, the fluorine noted by Switzer and Bailey (1954) in their analysis of afwillite from Crestmore, was probably due to the unsuspected presence of bultfonteinite, since there is no practical difference, other than grain size, in appearance between the two minerals.

A thin section of one massive afwillite-bultfonteinite vein showed that the latter mineral occurs as an irregular stringer roughly along the center line of the vein, in part replacing afwillite. This relationship is shown in the photomicrograph (Fig. 1), taken with crossed nicols.

X-Ray Study

A good *x*-ray powder photograph was obtained from the Crestmore material, showing a distribution of spacing and intensities which matched no published pattern. Fortunately, through the kindness of Professor C. E. Tilley of Cambridge University, a little of the type mineral from South Africa was made available, and a reference pattern recorded. The two patterns showed a close correspondence, with the exception of a few lines in the Crestmore film which could be accounted for by the presence of a small amount of calcite impurity in the sample. All bultfonteinite lines down to a spacing of 2.45 Å have been readily indexed, using the unit cell data given below. Table 1 lists the powder data, using the average of several Crestmore specimens, and compared with the type material.

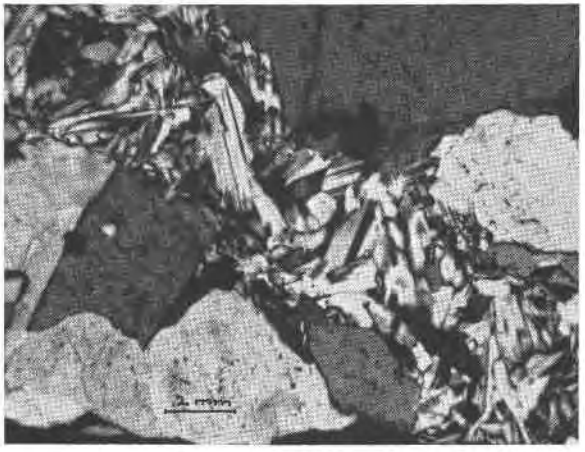

Fig. 1. Vein of bultfonteinite in afwillite. Magnification shown by .2 mm. scale. Crossed nicols, showing multiple twinning.

TABLE 1. X-RAY POWDER DATA FOR BULTFONTEINITE, IRON RADIATION, MANGANESE FILTER, IN ANGSTROM UNITS. $FeK_\alpha = 1.9373$

Crestmore		South Africa			
d/n measured	*I*	*d/n* measured	*I*	*d/n* calcul.	*hkl*
10.29	½			11.18	010
8.16	7	8.12	6	8.33	100
6.53	3	6.51	2	6.71	110
5.46	3	5.47	2	5.59	020
				4.16	200
4.065	3	4.06	4	4.14	111
3.98	½	3.95	½	4.02	$0\bar{2}1$
3.83	½			3.89	021
3.65	½	3.636	½	3.69	$\bar{1}21$
3.59	½	3.60	½	3.615	$\bar{1}21$
3.51	5	3.50	4	3.48	121
3.46	5	3.44	4	3.44	$\bar{2}01$
				3.40	130
3.35	½	3.33	½	3.34	220
				3.337	$2\bar{1}1$
3.27	½	3.26	½	3.268	$\bar{2}11$
				3.244	201
3.11	½			3.111	$2\bar{1}1$
2.92	10	2.92	6	2.958	$\bar{2}\bar{1}1$
2.885	10	2.88	6	2.913	$\bar{2}21$
2.825	4	2.825	2	2.834	$2\bar{2}1$
2.78	4	2.77	4	2.785	$2\bar{2}1$
				2.775	300
2.75	3	2.743	3	2.757	$0\bar{1}2$
2.72	½	2.72	2	2.718	012
2.625	½	2.634	½	2.637	140, $\bar{1}12$
2.48	½			2.467	041
2.45	½			2.441	231
2.355	½	2.36	½		
2.34	½	2.333	½		
2.28	½	2.272	½		
2.21	1				
2.19	½	2.195	3		
2.12	3				
2.093	2	2.118	4		
2.037	4	2.037	5		
1.99	3	1.988	2		
1.956	½	1.953	½		
1.93	8	1.93	10		
1.91	½	1.912	½		
1.89	1	1.887	½		
1.855	½	1.847	½		
1.73	1	1.751	½		
		1.729	½		
1.714	3	1.709	5		
1.687	½	1.686	½		
1.667	1	1.665	½		
1.63	1	1.638	3		
		1.614	½		
1.60	1	1.60	½		
1.54	½	1.541	½		
1.48	2	1.487	2		
1.426	2	1.413	2		
1.375	½	1.371	1		
1.35	2	1.348	2		
1.31	½	1.306	1		
1.07	½	1.074	1		

TABLE 2. BULTFONTEINITE
ANGLE TABLE

Triclinic; Pinacoidal $\bar{1}$. $a:b:c=0.7461:1:0.5078$, $\alpha=91°36'$, $\beta=93°53'$, $\gamma=89°54\frac{1}{2}'$, $p_0:q_0:r_0=0.6805:0.5067:1$. $\lambda=88°24'$, $\mu=86°06'$, $\nu=90°00'$, $p_0'=0.6823$, $q_0'=0.5081$, $x_0'=0.06815$, $y_0'=0.0280$.

Forms			ϕ	ρ	A	B	C
Old		New					
001	c	001	67°40′	4°13′	86°06′	88°24′	0°00′
100	b	010	0 00	90 00	90 00	0 00	88 24
010	a	100	90 00	90 00	0 00	90 00	86 06
210		140	18 34½	90 00	71 25½	18 34½	87 14½
110		120	33 53	90 00	56 07	33 53	86 29½
120	m	110	53 20	90 00	36 40	53 20	85 55
$1\bar{4}0$		$2\bar{1}0$	110 25	90 00	20 25	110 25	86 54½
$1\bar{2}0$	M	$1\bar{1}0$	126 40	90 00	36 40	126 40	87 55
$1\bar{1}0$		$1\bar{2}0$	146 07	90 00	56 07	146 07	88 09
$2\bar{1}0$		$1\bar{4}0$	161 25½	90 00	71 25½	161 25½	89 44
102	w	011	7 15	28 23	86 33½	61 52	26 32
101		021	3 42	46 34	87 19	43 33	44 51
$\bar{1}02$	W	$0\bar{1}1$	171 55	25 52	86 29	115 35½	25 08
$\bar{1}01$		$0\bar{2}1$	176 05½	45 00½	87 14½	134 52	46 28½
011	e	101	87 52	36 55	53 06½	88 43	33 00
$0\bar{1}1$	E	$\bar{1}01$	−87 23	31 35	121 33	88 38	35 26
112		122	37 22	34 00	70 10	63 37	30 25½
211		141	20 01	65 29	71 51	31 15	62 41
111		121	35 42½	52 07½	62 33	50 08	48 35
$\bar{1}11$		$1\bar{2}1$	142 47	51 08	61 44	128 19	50 10
$1\bar{1}1$		$\bar{1}21$	−30 28	50 27½	113 01	48 20½	51 11
$\bar{1}\bar{1}1$		$\bar{1}2\bar{1}$	−148 08	49 19	113 36	130 06	52 46

Transformation formula: Parry, Williams, Wright to Murdoch 010/200/001.

None of the Crestmore mineral was other than microscopic in grain size, but the type specimen from Professor Tilley was in the form of coarsely crystalline prismatic fragments. From these it was possible to select a relatively simple appearing sliver, which could be rather readily oriented on the c-axis, and since no x-ray determinative work had been done on the mineral, it was decided to see whether a satisfactory cell-determination could be made. Accordingly, a rotation photograph, and equator, first and second layer-line pictures, all about the prism-axis, were taken with filtered copper radiation.

These pictures were successful, and the reciprocal lattice plotted from the layer-lines showed a consistent pattern which appeared to be monoclinic. However, since Wright's optical study showed the mineral to be triclinic, this must be pseudomonoclinic, with $V=90°$ (within the limits of measurement). Twinning on both (100) and (010), is shown by the

presence of quadruplicate points on the plot, matching those shown by Wright (1932, p. 154), in the gnomonic projection of forms.

Cell dimensions, measured on the rotation picture for c_0, and calculated from the layer line pictures for a_0 and b_0, are as follows: $a_0 = 8.34$ Å, $b_0 = 11.18$ Å, $c_0 = 5.68$ Å, which reduce to an axial ratio of 0.7461 : 1 : 0.5078.

On comparing this ratio with the morphological data it is seen that agreement is very close, if Wright's a and b axes are exchanged and the new b axis taken at twice his value.

Parry, Williams & Wright original:	0.6756:1:0.6873
Parry, Williams & Wright re-valued:	0.7401:1:0.5087
Murdoch from x-ray:	0.7461:1:0.5078

The crystallographic work done on rather poorly terminated crystals, was remarkably accurate, and the newly chosen setting has been made on the basis of the x-ray findings, and to place the pole of (001) in the normally accepted triclinic position, i.e. forward and to the right of center in the gnomonic projection. The following Table 2 gives the revised crystallographic constants for the new position, the original forms, the new angles for reported forms, and the translation formula from old to new orientation.

The author wishes particularly to express his thanks to Professor C. E. Tilley, without whose kindness the measurements of cell dimensions and form would not have been possible.

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