CALEDONITE

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Caledonite is a basic sulphate of copper and lead, concerning which there has long been doubt both as to its composition and its symmetry. It was first described by Brooke (1820) as a sulphato-carbonate of orthorhombic crystallization. The carbonate constituent was later thought to be derived from admixed cerussite, and Dana (1892) made it a sulphate. But the last published analysis of it by Berg (1901), discussed on a later page of this paper, seems to establish the correctness of the first determination. Although we have made no new analysis, we were able to make certain that crystals of the mineral dissolve with vigorous effervescence in nitric acid, depositing lead sulphate.

Schrauf (1871) first cast doubt on the orthorhombic symmetry of caledonite. Schrauf, and after him Jeremejew (1882), interpreted minute differences of equivalent angles and slight re-entrant angles on faces in the vertical zone as indicating monoclinic symmetry more or less concealed by basal twinning. Neither they nor any later observers were able to detect any optical evidence which supported the assumed aggregate structure; still the doubt remained. We are indebted to Dr. Berman for a careful optical examination of selected crystals. The only ones at hand which showed the re-entrant angles on the front pinacoid as described by Schrauf were from the type locality, Leadhills, Scotland. Sections normal to the two pinacoids were prepared and studied for discontinuities such as twinning should produce. In one or two preparations a discontinuity could be seen but the evidence was not deemed adequate to prove twinning. It could be equally well explained as due to subparallelism, especially as so few of the sections examined showed even the slightest optical discontinuity. These results agree with the morphological and x-ray evidence in confirming the orthorhombic symmetry of caledonite. This conclusion is in agreement with all recent morphological studies. The evidence is excellently summarized in Hintze (1929).

Material for a renewed study of this mineral was found in an undescribed specimen from the Talisman Mine, Beaver Creek, Utah, No. 66912 of the Harvard Mineralogical Collection. It is a small hand specimen of rock intersected by numerous narrow open veinlets on whose walls are crystals of cerussite, linarite and caledonite. The crystals of the last-named mineral are of a clear blue-green color and of high lustre and perfection. They closely resemble, except as to brilliance, specimens from

the type English and Scottish localities, Cumberland and Leadhills, which were included in the study.

The position chosen by Brooke and Miller (1852) for caledonite with the *a* axis in the direction of the usual elongation has been followed by most later observers. But Greg and Lettsom (1858) took the elongation of the crystals as the *c* axis following Haidinger and Mohs (1839); and Schrauf (1871), to conform to his monoclinic interpretation, took the elongation as *b*, the symmetry axis. The lattice determination of Mr. Richmond makes the position of Greg and Lettsom the conventional one

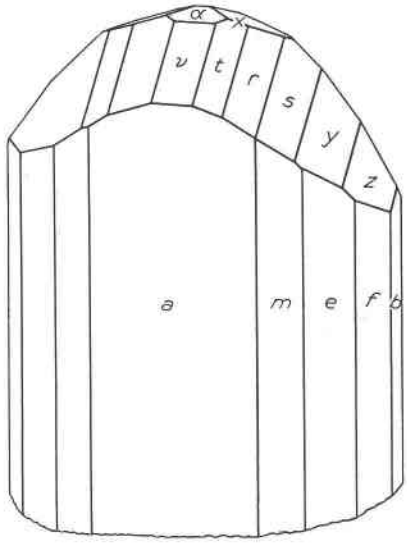

FIG. 1. Crystal of Caledonite from the Talisman Mine.

but with a doubled *b* axis. We adopt this usage; the doubled *c* axis (position of Brooke-Miller) had already been used by Ungemach (1912).

Goldschmidt in the Winkeltabellen (1897, p. 398) gives the elements of four observers and takes the mean as the best value to employ. Our measurements lead to values falling within the same range and we have therefore used Goldschmidt's elements and his angles, suitably transformed to the new position and unit form. Letters used for the forms follow Dana and Goldschmidt, except for the unit orthodome and the unit prism. Transformation formulas relating the various positions are as follows:—

Brooke and Miller to Palache	010/002/100
Greg and Lettsom to Palache	100/020/001
Schrauf to Palache	100/002/010

TABLE 1. CALEDONITE: ANGLE TABLE

Orthorhombic; dypyramidal—$2/m\ 2/m\ 2/m$
$a:b:c=0.3555:1:0.3263$; $p_0:q_0:r_0=0.9180:0.3263:1$
$q_1:r_1:p_1=0.3555:1.0893:1$; $r_2:p_2:q_2=3.0647:2.8134:1$

	ϕ	$\rho=C$	ϕ_1	$\rho_1=A$	ϕ_2	$\rho_2=B$	G & L	B & M	Sch.
b 010	0°00′	90°00′	90°00′	90°00′	—	0°00′	010	001	001
a 100	90 00	90 00	—	0 00	0°00′	90 00	100	010	100
h 1.32.0	5 01½	90 00	90 00	84 58½	0 00	5 01½	—	0.1.16	1.0.16
g 1.16.0	9 58½	90 00	90 00	80 01½	0 00	9 58½	—	018	108
k 1.12.0	13 11½	90 00	90 00	76 48½	0 00	13 11½	—	016	106
i 1.10.0	15 43	90 00	90 00	74 17	0 00	15 43	150	015	—
o 180	19 22½	90 00	90 00	70 37½	0 00	19 22½	—	014	—
ψ 160	25 07½	90 00	90 00	64 52½	0 00	25 07½	—	013	$\bar{1}03$
f 140	35 07	90 00	90 00	54 53	0 00	35 07	—	012	±102
κ 130	43 09½	90 00	90 00	46 50½	0 00	43 09½	—	023	—
e 120	54 35½	90 00	90 00	35 24½	0 00	54 35½	110	011	+101
m 110	70 26	90 00	90 00	29 34	0 00	70 26	—	021	$\bar{2}01$
x 011	0 00	18 04½	18 04½	90 00	90 00	71 55½	012	201	—
d 021	0 00	33 07½	33 07½	90 00	90 00	56 52½	—	101	—
α 102	90 00	24 39½	0 00	65 20½	65 20½	90 00	—	—	—
r 101	90 00	42 33	0 00	47 27	47 27	90 00	101	110	110
β 201	90 00	61 25½	0 00	28 34½	28 34½	90 00	—	—	—
l 111	70 26	44 15	18 04½	48 53½	47 27	76 29	212	221	±221
r 121	54 35½	48 24	33 07½	52 27	47 27	64 19½	111	111	±111
s 131	43 09½	53 18½	44 23½	56 44	47 27	54 12	232	223	±223
y 141	35 07	57 55½	52 32½	60 49½	47 27	46 07½	—	—	—
z 151	29 22	61 53½	58 29½	64 22½	47 47	39 46	—	—	—
τ 161	25 07½	65 11	62 56½	67 20	47 27	34 44	—	113	—

Uncertain forms:

Schrauf {1.48.0}, {1.40.0}, {1.24.0}, {1.20.0}, {3.10.3}, {787}, {10.1.10}.
Other authors {241}, {201}, and {151}.

Four crystals of caledonite from the Talisman Mine were measured and yielded several new forms as well as most of the well-established forms previously recorded. The prism zone is, as in all described crystals, much striated. However, distinct faces of *f*, κ, *e*, and *m* were observed. The terminal faces are sharp and in exceptionally accurate position, as may be seen from the following summary of measured angles on the crystal reproduced in the figure with but slight idealization.

TABLE 2. CALEDONITE: MEASURED ANGLES ON THE TERMINATION OF ONE CRYSTAL

	Mean		Range		No. of faces
	ϕ	ρ	ϕ	ρ	
011	0°03′	18°10′	0°17′– 0°24′	—	2
*102	90 10	24 33½	90 02 –90 19	24°30′–24°17′	2
101	90 06	42 33½	90 02 –90 10	42 26 –42 41	2
*201	90 00	61 28	—	—	1
111	70 26	44 17	70 22 –70 35	44 08 –44 25	4
121	54 30	48 30	—	48 22 –48 38	2
131	43 10	53 22½	43 03 –43 18	53 14 –53 32	4
*141	35 07½	58 02	35 06 –35 09	57 57 –58 07	2
*151	29 18	62 05	—	—	1
161	25 10	65 13	25 07 –25 14	65 12 –65 15	2

* New forms.

The forms (102) and (141) were found on two other crystals and are well established. The forms (201) and (151) since each was seen but once, may be held in some doubt, although the position of each was excellent. The latter took the place of a face of (161) in the quoin of the crystal where it occurred.

Optical properties. The optical data on caledonite have been revised by Dr. Berman. In the new orientation, they are:—

$X=c^*=1.818$	Biaxial negative
$Y=a=1.866$	$2V=85°\pm$
$Z=b=1.909$	$r<v$ slight

X-RAY EXAMINATION OF CALEDONITE
BY W. E. RICHMOND

The crystal fragment used for the *x*-ray study was a cleavage fragment separated from a larger crystal which showed macroscopically some evidence of aggregate structure. Special care was taken to select a fragment consisting of a single individual. The crystal was mounted so as to rotate about an axis normal to the perfect cleavage {010}, since this direction was the symmetry axis of the monoclinic interpretation of Schrauf. *X*-ray rotation photographs and zero, first and second layer-line Weissenberg photographs were taken about this axis. The first and second layer-line photographs revealed no evidence of monoclinic sym-

*Indices from Larsen's tables. The orientation there given $X=b$, which follows Dana, doubtless came from Descloizeaux. The latter gives $X=a$, which is correctly quoted by Hintze. Dana is in error as is Larsen. Dr. Berman checked the orientation, as given above, on crystals from Utah and Leadhills.

metry; they thus compel the conclusion that the mineral is orthorhombic as indicated by morphological study.

The lattice constants derived from the photographs are:—

$a_0 = 7.14$Å $\quad a_0:b_0:c_0 = 0.356:1:0.326$[5]
$b_0 = 20.06$Å $\quad a.b:c = 0.3555:1:0.3263$ (morphology)
$c_0 = 6.55$Å $\quad V_0 = 938.3$ cub. Å

The space group is $D_{2h}^{13} - P_{nmm}$ determined by the reflections:

(hkl) all present
($0kl$) with $k+l$ even
($h0l$) all present
($hk0$) all present

Content of the unit cell. A new value for the specific gravity was determined on single crystals with the micro-torsion balance, $G = 5.76 \pm .01$. The analysis chosen for discussion was that published by Berg (1901), since his description of the preparation of the analysis sample indicates that special care was used to avoid contamination by cerussite. The following table exhibits the results obtained using V_0 and G as stated above.

TABLE 3. COMPOSITION OF CALEDONITE

	1	2		3	4	5
CuO	9.73	0.122	Cu	0.122	4.00	4
PbO	69.18	0.310	Pb	0.310	10.13	10
CO_2	3.16	0.072	C	0.072	2.36	2
SO_3	14.15	0.177	S	0.177	5.80	6
H_2O	3.78	0.209	H	0.418	13.67	12
	100.00		O	1.316	43.10	42

1. Analysis of caledonite from Challocolla, Chile, recalculated to 100 per cent. Analyst Liebert in Berg (1901).
2. Molecular proportions.
3. Atomic proportions.
4. Number of atoms in the unit cell.
5. Assumed theoretical number of atoms in unit cell.

The cell formula is therefore

$$2[Cu_2Pb_5(SO_4)_3(CO_3)(OH)_6].$$

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