AN X-RAY STUDY OF LEIGHTONITE

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ABSTRACT

Leightonite is orthorhombic, holohedral, with *a* 11.67 Å, *b* 16.52 Å, *c* 7.492 Å; *a*:*b*:*c* = 0.7064:1:0.4535; not triclinic as previously considered. The space group is *Fmmm*, and the unit cell content is $4[K_2Ca_2Cu(SO_4)_4.2H_2O]$. An angle table and *x*-ray powder photograph data are included, as well as a list of associated minerals. The similarity of leightonite to polyhalite $(K_2Ca_2Mg(SO_4)_4.2H_2O]$ is discussed.

INTRODUCTION

Leightonite is a hydrous copper potassium calcium sulphate which has been found only in the Chuquicamata mine in Atacama province, Chile. It was first described in 1938 by Charles Palache. His study of this mineral, named in honour of Dr. Thomas Leighton of the University of Santiago, Chile, led Palache to the conclusion that in spite of its holohedral orthorhombic morphology, leightonite was triclinic. This conclusion was based upon a reflecting goniometer study which Palache claimed showed repeated lamellar twinning of a near-rectangular triclinic lattice about the vertical axial planes, expressed through striations on the {101} faces of the crystals. On the basis of these observations, leightonite is listed as a triclinic mineral in the second volume of Dana's System of Mineralogy.

At Chuquicamata, leightonite occurs in the great open pit, where it is limited to a zone within fifty metres of the original surface. It is found in marginal material, never in rich ore, and is considered to have formed under conditions of low acidity. Although aggregates of well-formed crystals are found in crevices, more commonly the mineral occurs as cross-fibre veinlets.

Leightonite is pale, watery blue-green in colour, translucent, and possesses a vitreous lustre. Hardness is 3, and according to Palache, the specific gravity of the mineral is 2.95. Leightonite exhibits no cleavage.

We were fortunate in obtaining a well-crystallized specimen (ROM 19490) from the collection of the Royal Ontario Museum. This specimen is composed of pale, watery blue-green massive leightonite with many

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small (up to 4 mm.) subhedral to euhedral crystals covering the surface. Several other minerals, listed below, are also present on the specimen.

OPTICS

An examination of the major indices of refraction, using the oil immersion technique, served to establish the identity of the mineral as leightonite. Table 1 shows that the optical constants agree very well with those obtained by Palache in his study of leightonite. However, careful examination of several excellent thin sections of single crystals, cut normal to morphological axial directions, indicated that, within the limits of measurement, extinction in all three axial directions is parallel. Furthermore, inspection of a large number of crystal fragments under immersion oils failed to turn up any evidence of the multiple twinning described by Palache. We were forced to the conclusion that so far as its optics are concerned, leightonite displays orthorhombic symmetry.

TABLE 1. LEIGHTONITE: OPTICAL OBSERVATIONS

	1			2		
α	near *b*	1.578	±0.002	parallel to *b*	1.574	±0.002
β	near *c*	1.587		parallel to *c*	1.587	
γ	near *a*	1.595				

1. Palache, 1938. 2. This paper.

MORPHOLOGY

A particularly well-formed crystal of leightonite was oriented on the Goldschmidt two-circle goniometer with the *c* axis, as chosen by Palache, as the axis of adjustment. The measurements obtained are shown in Table 2. The faces of the form *e*{101} on every crystal are deeply striated

TABLE 2. LEIGHTONITE: MEASURED AND CALCULATED ANGLES

	This paper				Palache[b] Calculated	
	Measured		Calculated[a]			
Form	ϕ	ρ	ϕ	ρ	ϕ	ρ
b (010)	0°00′	90°00′	0°00′	90°00′	0°00′	90°00′
a (100)	91°20′	90°00′	90°00′	90°00′	90°00′	90°00′
m (110)	55°20′	90°00′	54°50′	90°00′	54°50½′	90°00′
e (101)	91°20′	32°30′	90°00′	33°04′	90°00′	33°01½′
p (111)	54°50′	38°22′	54°50′	38°22′	54°50½′	38°29′
d (031)	0°00′	52°55′	0°00′	53°58′	0°00′	53°56½′
q (131)	25°35′	56°53′	25°18′	56°40′	25°19½′	56°39′

[a] $a:b:c = 0.7043 : 1 : 0.4583$.

[b] $a:b:c = 0.7043 : 1 : 0.4578$.

parallel to $c\{010\}$. Palache ascribes this to alternation of the forms $e\{101\}$ and $q\{131\}$. On the material available to us, however, the form alternating with e is $p\{111\}$.

Broadly speaking, two different habits could be discerned on the material studied, and there are present nearly all variations between the two. Drawings of these habits are shown in Fig. 1.

Leightonite is orthorhombic holohedral in its morphology.

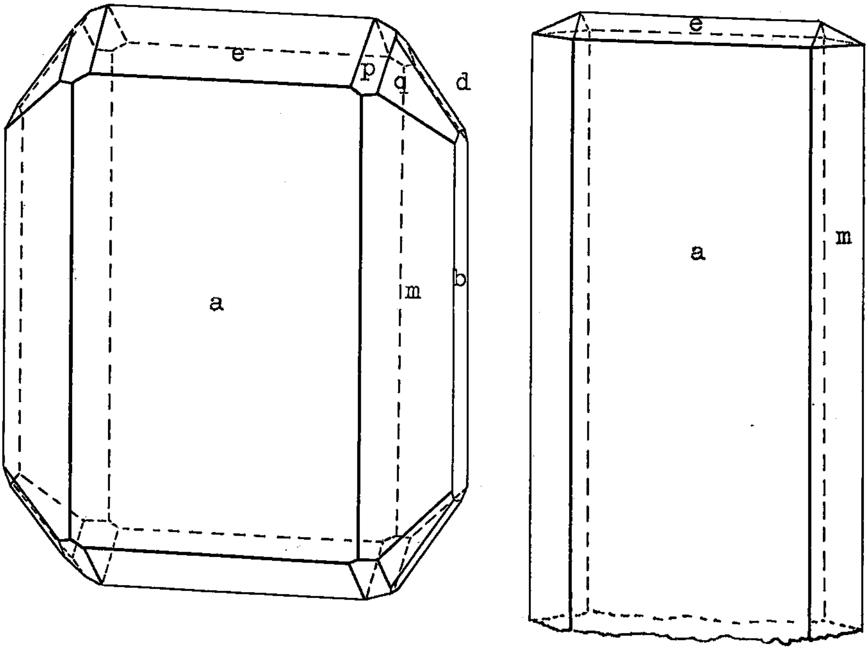

FIG. 1. Leightonite, Chile, with crystal forms: b {010}, a {100}, m {110}, e {101}, d {031}, p {111}, q {131}.

X-RAY MEASUREMENTS

A well-developed crystal free of visible inclusions was oriented on the optical goniometer so as to rotate about a morphological crystal axis, and a rotation photograph, zero and first-layer Weissenberg photographs were taken, using unfiltered copper radiation. This process was repeated about the other two axes of the crystal, omitting Weissenberg photographs for the third orientation. From measurements of the rotation films, the following periods were obtained:

$$a = 11.67\ \text{Å};\quad b = 16.52\ \text{Å};\quad c = 7.49\ \text{Å}$$

with the ratio $a:b:c = 0.7064:1:0.4535$.

The Weissenberg films show orthorhombic symmetry, and plotting of the diffractions resulted in the emergence of a clearly orthorhombic direct lattice, which on inspection was seen to be all-face-centred. The ratio compares very favourably with the morphological ratio determined by goniometric examination. There is, then, apparently a simple relationship between the unit structure and its external morphological expression.

An examination of the extinction conditions showed that the only reflection absences were those which indicate full face-centring. This places leightonite in the space group *Fmmm.*

There is no evidence in the films of twinning, and it definitely does not appear to be a factor in determining the symmetry of the mineral. (A few extra spots on the films appear to be the result of a small satellite crystal.)

The usual powder data for leightonite are given in Table 3. Indexing of the reflections was carried out both by using the standard formula and through Peacock's graphical method (1939).

TABLE 3. LEIGHTONITE: *X*-RAY POWDER DATA
Cu/Ni radiation, $K\alpha = 1.5418$ Å

I	*d* (meas.)	*d* (calc.)	(*hkl*)	*I*	*d* (meas.)	*I*	*d* (meas.)
5	5.98	5.83	(200)	5	1.866	5	1.222
2	4.13	4.13	(040)	30	1.781	1	1.192
5	3.39	3.37	(240)	5	1.710	5	1.112
		3.47	(022)	2	1.629	10	1.047
60	3.18	3.16	(202)	5	1.590	1	0.9906
100	2.90	2.94	(222)	7	1.517	2	0.9399
10	2.51	2.51	(242)	10	1.461	1	0.8527
		2.49	(260)	7	1.347	1	0.8362
10	2.40	2.39	(351)	2	1.293	5	0.8065
		2.38	(440)	2	1.262		
20	2.22	2.22	(062)				
			(422)				
2	2.07	2.01	(442)				

COMPOSITION AND CELL CONTENTS

Table 4 gives the only published analyses of leightonite together with the cell contents calculated with the aid of the relationship $MW \times Z = V \times D/1.66$, where D is 2.95 (Palache, 1938). These three analyses show close agreement, the chief impurity is soda, which replaces the potash in varying amounts. The calculations confirm the generally accepted formula, and indicate that the cell contents are

$$4[K_2Ca_2Cu(SO_4)_4 \cdot 2H_2O]$$

TABLE 4. LEIGHTONITE: ANALYSES AND CELL CONTENT
Cell Volume = 1444.4 Å^3

	1		2		3		4	
	A	B	A	B	A	B	A	B
K_2O	13.62	4.10	13.93	4.01	13.8	3.8	4	14.68
Na_2O	0.98		0.56		tr.			
CaO	17.50	7.97	18.41	8.39	17.3	8.0	8	17.45
CuO	11.24	3.61	11.97	3.85	12.2	4.0	4	12.39
SO_3	50.75	16.19	49.33	15.76	48.8	15.85	16	49.87
H_2O	5.98	8.46	5.71	8.10	7.0	9.92	8	5.61
Total	100.07		99.91		99.1			100.00

1. Gonyer (in Palache, 1938); on cross-fibre material.
2. Gonyer (in Palache, 1938); on crystals.
3. Carter (in Palache, 1938); cross-fibre material. A—as analysed; B—calculated cell contents.
4. A—ideal cell contents; B—ideal weight per cent.

ASSOCIATED MINERALS

Several mineral species were found on the specimen of leightonite studied. They were identified as follows:

Gypsum, $CaSO_4.2H_2O$, is the most abundant of the associated minerals, and occurs as a white, opaque powder, as small sheets of selenite, and rarely as pseudomorphs after leightonite.

Quartz occurs as small to medium, opaque, white, anhedral grains.

Atacamite, $CuCl_2.3Cu(OH_2)$, is found as small, beautifully euhedral opaque, deep emerald-green crystals scattered over the surface of the specimen.

Bloedite, $MgNa_2(SO_4)_2.4H_2O$, occurs as very small, rounded equant crystals of perfect transparency, absolutely colourless. These are scattered sparsely over the specimen.

Natrochalcite, $Na_2Cu_4(SO_4)_4(OH)_2.2H_2O$, occurs as sub-rounded, anhedral grains, sub-translucent to opaque, and lime-green in colour. Bandy (1938) lists natrochalcite as another mineral which occurs only at Chuquicamata.

LEIGHTONITE AND POLYHALITE

It is interesting to note that leightonite has a chemical homologue—polyhalite, $K_2Ca_2Mg(SO_4)_4.2H_2O$. Polyhalite has not at this writing[2] been studied by single crystal *x*-ray methods, but its morphology is known to be sensibly triclinic (Görgey, 1915; Peacock, 1938). In this

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[2] Editor's note: Braitsch (1961) reports dimensions for polyhalite: Triclinic, $F\bar{1}$, $a = 11.683$, $b = 16.332$, $c = 7.599$ Å, $\alpha = 90° 34'$, $\beta = 90° 6'$, $\gamma = 91° 54'$, $Z = 4$.

respect it is now seen to differ from leightonite. Why this is so may be related to the difference in ionic radius of Mg^{2+} and Cu^{2+}, although this difference is not very great (0.67 and 0.72 Å respectively, according to Ahrens, 1952). Unfortunately, solution of this intriguing problem must await closer study of both minerals.

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