

# STERRETTITE, A NEW MINERAL FROM FAIRFIELD, UTAH

ESPER S. LARSEN, 3d., *Harvard University, Cambridge, Mass.*,

AND

ARTHUR MONTGOMERY, *New York City.*

(Contribution from the Department of Mineralogy and Petrography,  
Harvard University, No. 226.)

## ABSTRACT

*Sterrettite*,  $\text{Al}_6(\text{PO}_4)_4(\text{OH})_6 \cdot 5\text{H}_2\text{O}$ , is found in cavities in pseudowavellite in the variscite deposit near Fairfield, Utah. It occurs in orthorhombic, colorless, simple prismatic crystals. Cleavage: {110} fair, {100} and {001} poor.  $H=5$ ;  $G=2.36$ . Biaxial neg.,  $2V=60^\circ \pm 10^\circ$ ;  $r > v$ , barely perceptible;  $X=a$ ,  $Y=b$ ;  $\alpha=1.572$ ,  $\beta=1.590$ ,  $\gamma=1.601$ , all  $\pm 0.003$ . Elements (morphological):  $a:b:c=0.8662:1:0.5325$ . Structural lattice: space group  $P2_12_12_1$ ;  $a_0=8.90\text{\AA}$ ,  $b_0=10.20\text{\AA}$ ,  $c_0=5.43\text{\AA}$ ;  $a_0:b_0:c_0=0.872:1:0.532$ ; cell contains  $\text{Al}_6(\text{PO}_4)_4(\text{OH})_6 \cdot 5\text{H}_2\text{O}$ . Named after Dr. Douglas B. Sterrett, one of the first to investigate and describe the Utah and Nevada variscite deposits.

From a large amount of material from the variscite deposit near Fairfield, Utah (Larsen and Shannon, 1930; Larsen, 1940), collected by Messrs. Arthur Montgomery and Edwin Over, a few specimens contain orthorhombic crystals distinct from any previously described mineral. With considerable difficulty sufficient material was purified for a chemical analysis.

The mineral is named *sterrettite* in honor of Dr. Douglas B. Sterrett who was one of the first investigators of the Utah and Nevada variscite deposits.

## OCCURRENCE

Sterrettite is colorless and occurs as tiny single crystals, nearly all of which are excellent for goniometric measurement. They are present only in a tan-colored massive pseudowavellite which has tiny irregular pores through it, and in lenticular openings between curving outer shells of the pseudowavellite. The crystals grew with the prism zone normal to the walls of these openings, commonly one crystal to an opening. Knobs and spherules of pseudowavellite projecting into cavities may have several crystals growing from their surfaces in a radial arrangement, but each crystal is separate and perfect. Hexagonal prisms of a member of the apatite group occur in some cavities in the pseudowavellite, but their relation to sterrettite is not shown.

## MORPHOLOGY

Sterrettite is orthorhombic and prismatic in habit. The crystals are slightly elongated in the [100] zone, which is the prismatic zone of Fig. 1,

and range in maximum dimension from 0.25 to 1.0 millimeter. It is the only mineral found in the nodules forming crystals free of vicinal forms and subparallel growths. The setting chosen is that indicated by the  $x$ -ray study.

Seven crystals were measured on the goniometer. The measured range of angles and the best average angles of the observed faces are shown in Table 1. Table 2 gives the formal angle table.

TABLE 1. STERRETTITE—RANGE AND WEIGHTED AVERAGE OF OBSERVED ANGLES TOGETHER WITH THE CALCULATED ANGLES

Form	No. obs.	Measured Range		Best Average		Calculated	
		$\phi$	$\rho$	$\phi$	$\rho$	$\phi$	$\rho$
<i>b</i> 010	7	—	89°53'–90°48'	0°00'	89°59'	0°00'	90°00'
<i>a</i> 100	7	—	—	90 00	90 00	90 00	90 00
<i>m</i> 110	13	48°54'–49°39'	89 13 –91 38	49 06	89 55	49 06	90 00
<i>w</i> 011	28	—	27 18 –28 47	0 00	28 02	0 00	28 02
<i>v</i> 031	1	—	—	0 00	57 55	0 00	57 57
<i>d</i> 101	3	89 56 –90 00	31 21 –31 38	89 59	31 30	90 00	31 34½

TABLE 2. STERRETTITE—ANGLE TABLE

Orthorhombic Disphenoidal— $P2_12_12_1$

$a:b:c=0.8662:1:0.5325$ ,  $p_0:q_0:r_0=0.6147:0.5325:1$

$q_1:r_1:1=0.8663:1.6268:1$

$r_2:p_2:1=1.8779:1.1545:1$

Form	$\phi$	$\rho=C$	$\phi_1$	$\rho_1=A$	$\phi_2$	$\rho_2=B$
<i>b</i> 010	0°00'	90°00'	90°00'	90°00'	—	0°00'
<i>a</i> 100	90 00	90 00	—	0 00	0°00'	90 00
<i>m</i> 110	49 06	90 00	90 00	40 54	0 00	49 06
<i>w</i> 011	0 00	28 02	28 02	90 00	90 00	61 58
<i>v</i> 031	0 00	57 57	57 57	90 00	90 00	32 03
<i>d</i> 101	90 00	31 34½	0 00	58 25½	58 25½	90 00

The crystals were measured with  $a\{100\}$  polar so that the well-developed  $[100]$  zone could be used to orient the crystals most accurately. The measured range of angles and the best average angles given in Table 1 have been recast from the actual measured values in the first inversion to their values in the normal setting; since no general  $\{hkl\}$  forms were present, the recasting to the normal setting was merely a matter of interchanging the measured values of  $\phi$  or  $\rho$ , or taking their supplements.

The prismatic habit is controlled by  $w\{011\}$ , which is always the dominant form in the  $[100]$  zone and reflects a very perfect signal. The pinacoid  $a\{100\}$  is always present as a large face, and is the only other important form. The front pinacoid  $a\{100\}$  invariably reflects multiple signals, commonly a central signal surrounded by many less distinct signals, none of which is more than two degrees from the polar position. The front pinacoid is shown in a sketch from typical crystals in Fig. 1 (c). Seen under the binocular this face is diamond-shaped with a distinct suture crossing it parallel to the long diagonal; other sutures are seen parallel to the short diagonal on some crystals, or radiating out from the center roughly normal to the  $(011)$  edge; faint striae cross the face perpendicular to the principal suture, or on some crystals at an angle to this. This constant suturing is ordinarily suggestive of twinning.

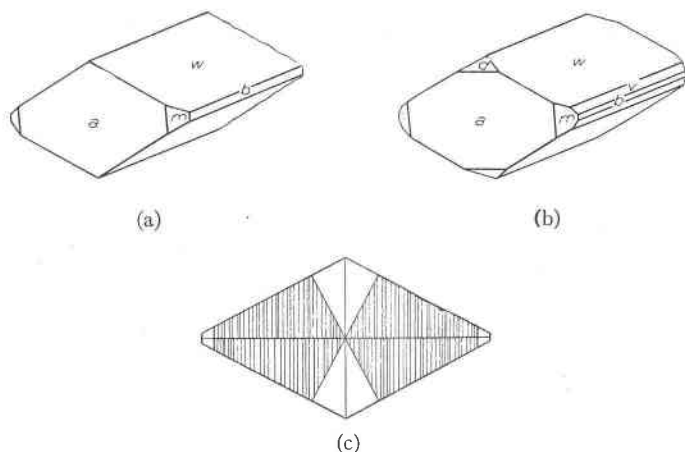


FIG. 1. Crystal drawings of sterrettite: (a) usual habit; (b) less common forms; (c) sketch of striae on  $a\{100\}$ .

The prism  $m\{110\}$  is present on nearly all of the crystals; it is usually small, although it reflects a good signal. On some crystals this face is bisected by a horizontal line, and the face reflects a double signal. The side pinacoid  $b\{010\}$  is present on many of the crystals, but is narrow, approaching a line-face on some; it reflects a good but in some cases a weak signal.

The dome  $d\{101\}$  is normally absent; when present, it is generally smaller than  $m\{110\}$ , and reflects a weak but good signal. On one crystal measured it was a large, perfect face. The face  $v\{031\}$  was observed once as a small but excellent face.

It is stated above that the suturing of the front pinacoid indicates twinning; the division of the  $m\{110\}$  faces likewise suggests twinning. Optically the crystals are completely continuous. Thus, if there is twinning, the twin axis must coincide with any one of the crystallographic axes. The  $x$ -ray study proves that the three crystallographic axes are polar, so that such twinning is possible. The evidence thus strongly indicates, if not proves, twinning about any one of the crystallographic axes, with  $\{001\}$  as the principal composition plane and perhaps  $v\{031\}$  as a subordinate composition plane. All of the crystals seen have apparently been twinned in this way.

Although most of the crystals are attached on the front pinacoid, a few could be seen to be doubly terminated.

#### PHYSICAL AND OPTICAL PROPERTIES

Sterrettite has a fair cleavage parallel to  $m\{110\}$ , and two poor cleavages, parallel to  $a\{100\}$  and  $\{001\}$ . It has a hardness of 5 and a specific gravity of 2.36 as determined by suspension in bromoform. It has a vitreous luster and is always colorless and clear.

The mineral is practically insoluble in hot acids. A sample was heated for twenty hours in concentrated HCl and less than two per cent of the mineral went into solution. In the closed tube it fuses readily and gives off water, leaving a dark infusible mass.

Its optical properties are:

$n$	
$\left. \begin{array}{l} X=a=1.572 \\ Y=b=1.590 \\ Z=c=1.601 \end{array} \right\} \pm 0.003$	Biax. neg., $2V=60^\circ \pm 10^\circ$ $r > v$ , barely perceptible Colorless.

#### STRUCTURAL ELEMENTS

Rotation, and zero and first layer Weissenberg photographs about  $[100]$  and rotation and zero layer Weissenberg photographs about  $[001]$  were taken. The following unit cell dimensions were derived from them:

$$\begin{aligned} a_0 &= 8.90\text{\AA}; & b_0 &= 10.20\text{\AA}; & c_0 &= 5.43\text{\AA}; & \text{all } &\pm 0.02\text{\AA}. \\ a_0:b_0:c_0 &= 0.872:1:0.532 \\ V_0 &= 493 \text{ cu.\AA}. & M_0 &= 705 \text{ for } d=2,36 \end{aligned}$$

The following are the only spectral omissions:

$$\begin{aligned} \text{For: } & (h00), h \text{ odd;} \\ & (0k0), k \text{ odd;} \\ & (00l), l \text{ odd.} \end{aligned}$$

This uniquely determines the space group  $P2_12_12_1-D_2^4$ . This proof of diphenoidal symmetry and the consequent polarity of all the crystal-

lographic axes conforms with the evidence of twinning mentioned in the section on the morphology. The fact that a twinned crystal was used in the  $x$ -ray study need not, in this case, be considered in the determination of the dimensions of the unit cell and the space group; twinning about a crystallographic axis in an orthorhombic mineral only places the positive (top) end of one twin unit in contact with the negative (bottom) end of the other. Since reflection of  $x$ -rays from the top of an orthorhombic crystal is identical with reflection from the bottom, a twin of this type will reflect  $x$ -rays exactly as an individual crystal.

## CHEMISTRY

A sample, 99 per cent pure as estimated by microscopic examination, weighing 185 milligrams, was analyzed by Mr. F. A. Gonyer. Water was determined by ignition on the whole sample. The ignited sample was divided into two equal parts, one for the determination of alkalis and the other for the remaining constituents. Since  $H_2O$ ,  $Al_2O_3$  and  $P_2O_5$  together totaled close to 100 per cent, alkalis were not determined. CaO and MgO were absent. The analysis is given in Table 3, together with

TABLE 3. ANALYSIS AND RATIOS OF STERRETTITE

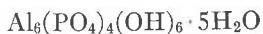
	A	B	1	2	3	4
$P_2O_5$	40.10	38.69	.282	P .564	3.98	4
$Al_2O_3$	39.07	41.67	.383	Al .766	5.40	6
$H_2O$	20.36	19.64	1.129	H 2.258	15.92	16
CaO	none			O 3.688	26.05	27
MgO	none					
	99.53	100.00				

A. Analysis of sterrettite by F. A. Gonyer. Sample weighed 185 mg. and was 99% pure.

B. Theoretical composition of  $Al_6(PO_4)_4(OH)_6 \cdot 5H_2O$ .

1. Molecular proportions calculated from A.
2. Atomic proportions.
3. Number of atoms in unit cell, assuming  $V_0 = 493$  cu. Å. and  $d = 2.36$ .
4. Theoretical number of atoms in unit cell.

the molecular and atomic ratios, and the number of atoms in the unit cell, assuming the specific gravity to be 2.36 and  $V_0 = 493$  cu. Å. The unit cell content is expressed by the formula:



The calculated specific gravity for this composition and the above volume of the unit cell is 2.45, which is in poor agreement with the measured value.

## RELATED MINERALS

Chemically sterrettite seems to be related to wavellite; the only difference between sterrettite and wavellite is that the former has less water. Optically they are very different. The axial ratios of sterrettite and metavariscite are comparable, if  $a$  and  $c$  are interchanged in sterrettite and the orientation of metavariscite is that of Strunz and Sztrokay (1939):

Sterrettite	$c:b:a=0.5325:1:0.8662$ , orthorhombic
Metavariscite	$a:b:c=0.5459:1:0.8944$ , monoclinic (?)

Sterrettite is comparable with variscite if  $c$  is doubled and interchanged with  $a$  and the orientation of variscite is that of Strunz and Sztrokay (*op. cit.*)::

Sterrettite	$2c:b:a=1.0650:1:0.8662$ , orthorhombic
Variscite	$a:b:c=1.0217:1:0.8918$ , orthorhombic

However, an  $x$ -ray powder photograph of sterrettite is completely different from those of variscite and metavariscite.\* Sterrettite is distinct from all other known hydrous basic aluminum phosphates in its optical and physical properties. It must therefore be a distinct species.

## ACKNOWLEDGMENT

The writers are indebted to Professor Charles Palache and Dr. Harry Berman for discussions concerning the probable twinning exhibited by sterrettite.

\* The metavariscite used was crystalline material from the type locality, Lucin, Utah.

## REFERENCES

- LARSEN, E. S., and SHANNON, E. V., The minerals of the phosphate nodules from near Fairfield, Utah: *Am. Mineral.*, **15**, 307-337 (1930).  
 LARSEN, E. S. 3d, Overite and montgomeryite: two new minerals from Fairfield, Utah: *Am. Mineral.*, **25**, 315-326 (1940).  
 STRUNZ, H., and SZTRKAY, K., Isodimorphie zwischen Metavariscit, Variscit, Phosphosiderit und Strengit; *Zeits. Min.*, pt. A, no. 9, 272-278 (1939).