

*Studies of mineral sulpho-salts: XV. Xanthoconite
and pyrostitpnite¹*

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IN his long conduct of the *Mineralogical Magazine* and *Mineralogical Abstracts* our Editor has always shown a ready interest and understanding for each new phase of mineralogy as it has appeared, and thus a contribution to any part of the wider realm of mineralogy would fall in the range of Dr. Spencer's comprehending appraisal. At the same time Dr. Spencer's own published work in mineralogy and the style of his abstracts of the works of others show that his personal interests incline to the classical natural history aspect of mineralogy, which gives first importance to exact observations that establish the individuality of new species, improve and extend the knowledge of well-defined species, or disprove the existence of supposed new minerals. And, therefore, in choosing a topic for this collection of papers in which we seek to honour our Editor and emphasize his influence on mineralogy, I have resisted an urge to wander from the straight path of descriptive mineralogy and have decided to bring together some notes, already a few years old, on a pair of still imperfectly known mineral sulpho-salts. Xanthoconite, $3\text{Ag}_2\text{S}\cdot\text{As}_2\text{S}_3$, and pyrostitpnite (fireblende), $3\text{Ag}_2\text{S}\cdot\text{Sb}_2\text{S}_3$, are the relatively rare, apparently monoclinic analogues of the ruby silvers, proustite and pyrargyrite. Both of the rarer species are known only as small imperfect crystals, and consequently there are crystallographic uncertainties which are best resolved by X-ray measurements. In anticipation of this paper the results of such measurements were briefly stated in two notes (1943, 1947); but apart from these observations the descriptions of the two species, as given in Dana (1944), are substantially as they stood after the work of Miers (1893) on xanthoconite and Luedecke (1882) on pyrostitpnite.

¹ Contributions to Mineralogy from the Department of Geological Sciences, University of Toronto, 1950, no. 5. No. XIV of this series is by Robinson (1948); no. XIII, by Peacock and Berry (1947), appeared in this *Magazine*.

² The sad news of Professor Martin Alfred Peacock's sudden death on October 30 was received during the preparation of this number.

For the present work the following specimens were assembled:

1. Xanthoconite, Píbram, Bohemia (Harvard Mineralogical Museum, 94799); yellow crystals of thick tabular to short columnar pseudo-orthorhombic habit (fig. 1).
2. Xanthoconite ('rittingerite'), Joachimsthal, Bohemia (HMM 82544); yellowish tabular pseudo-orthorhombic crystals (fig. 2).

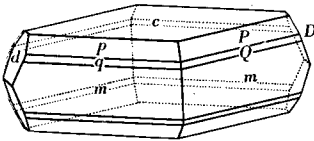


FIG. 1.

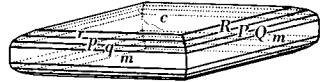


FIG. 2.

3. Xanthoconite, La Rose mine, Cobalt, Ontario (Royal Ontario Museum, M 14342); hemispherical crusts of minute buff crystals with occasional implanted crystals of proustite.
4. Pyrostitpnite, Píbram, Bohemia (HMM 94799); minute red laths, some twisted about the long edge.
5. Pyrostitpnite, Andreasberg, Harz (HMM 94802); stilbite-like group of minute red crystals (figs. 4, 5).
6. Pyrostitpnite, Randsburg, California; minute red lath-like crystals.

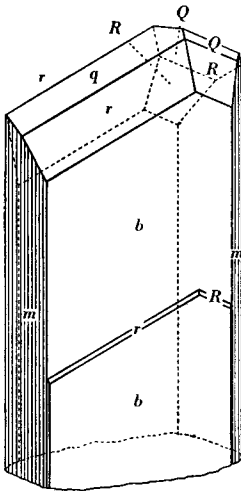


FIG. 4.

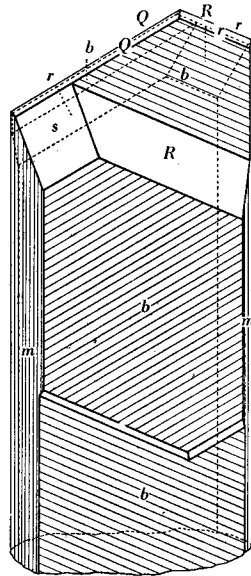


FIG. 5.

The specimens from the Harvard Mineralogical Museum were kindly lent for study by the late Dr. Harry Berman; the specimen from the

Royal Ontario Museum by Professor A. L. Parsons; and the crystals from California by Professor J. Murdoch (Los Angeles) who also sent

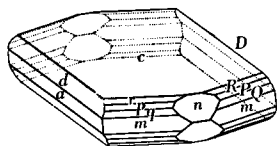


FIG. 3:

(table III).

me some unpublished two-circle measurements and a cell determination with permission to use them in this work. My thanks are also due to Dr. E. W. Nuffield who prepared the drawings for figs. 1-3 from my sketches, and to Dr. L. G. Berry who indexed the powder pattern of xanthoconite

XANTHOCONITE.

Crystal lattice and morphology.—This is a case where sharp X-ray photographs on a small crystal may be expected to give better geometrical elements than those obtained by the reflecting goniometer. A small equant fragment was obtained from a crystal from material no. 1; this gave excellent signals from $c(001)$ and $D(\bar{5}01)$ of Miers, permitting accurate adjustment for rotation about $[010]$, and poor signals from faces of the type (hhl) . A rotation photograph and Weissenberg resolutions of the zero and first layer lines gave a monoclinic lattice in which the simplest cell is base centred, with symmetry of the space group $C2/c$ and the dimensions:¹

$$a' = 11.97, b' = 6.20, c' = 16.95 \text{ kX}, \beta' = 110^\circ 10'$$

using $\text{Cu-K}\alpha^1 = 1.5374 \text{ kX}$. However, the typical habit of xanthoconite is pseudo-orthorhombic with frequently like development of (hhl) and $(\bar{h}hl)$ forms and common twinning on (001) , further accentuating the nearly rectangular lattice. It seems proper, therefore, to choose the corresponding unit cell which is face-centred, with the symmetry $F2/d$ and the cell edges $a = [\bar{1}00]$, $b = [0\bar{1}0]$, $c = [102]$, which give:

$$a = 11.97, b = 6.20, c = 31.82 \text{ kX}, \beta = 90^\circ 30\frac{1}{2}'.$$

This cell gives the following geometrical ratios as compared to Miers's final elements based on many old and new measurements:

$$a : b : c = 1.9307 : 1 : 5.1327; \beta = 90^\circ 30\frac{1}{2}' \text{ M. A. P. (X-ray)}$$

$$a : b : 5c = 1.9187 : 1 : 5.0760; \beta = 91^\circ 13' \text{ Miers (gon.)}$$

The agreement is not good, but this is not surprising in view of the

¹ All the unit-cell dimensions and spacings in this paper are based on $\text{Cu-K}\alpha_1 = 1.5374 \text{ kX}$ and the calculated densities on the mass factor 1.650. In \AA . as defined in 1947 the cell dimensions of xanthoconite are $a' = a = 11.99$, $b' = b = 6.21$, $c' = 16.98$, $c = 31.86$. M. A. P.

generally poor quality of the crystal faces which commonly do not allow a distinction to be made between (hhl) and $(\bar{h}hl)$ forms.

The transformation, old (Miers) to new (M. A. P.), is simply 100/100/005, which gives the comparison of symbols of the reported forms in table I. The new setting gives a net simplification of indices, and some apparent complications ($t T h H y Y \rho$) in which the transformed indices are, however, close to simple indices.

TABLE I. Xanthoconite: reported forms in old and new notations.

Old.	New.	Old.	New.
$a(100)$	$a(100)$	$H(\bar{3}34)$	$-(\bar{3}.3.20) \sim (\bar{1}17)$
$c(001)$	$c(001)$	$p(111)$	$p(\bar{1}15)$
$m(110)$	$m(110)$	$P(\bar{1}11)$	$P(\bar{1}15)$
$n(053)$	$n(013)$	$y(443)$	$-(4.4.15) \sim (114)$
$d(501)$	$d(101)$	$Y(\bar{4}43)$	$-(\bar{4}.4.15) \sim (\bar{1}14)$
$D(501)$	$D(\bar{1}01)$	$\rho(332)$	$-(3.3.10) \sim (113)$
$r(112)$	$r(1.1.10)$	$*u(553)$	$u(113)$
$R(\bar{1}12)$	$R(\bar{1}.1.10)$	$*z(553)$	$U(\bar{1}13)$
$z(223)$	$-(2.2.15) \sim (117)$	$*z(552)$	$z(112)$
$T(223)$	$-(\bar{2}.2.15) \sim (\bar{1}17)$	$q(551)$	$q(111)$
$h(334)$	$-(3.3.20) \sim (117)$	$Q(\bar{5}51)$	$Q(\bar{1}11)$

* Tokody (1930).

Table II compares interfacial angles calculated from the X-ray elements with measurements given by Miers (1893), which include observations by Breithaupt, Schabus, Streng, and Schrauf, by Tokody (1930), and new measurements on two crystals from material no. 1. It will be seen that the calculated angles mostly lie well in the range of the measured angles, and that many individual measurements (often representing angles to planes whose symbols were not determined as positive or negative) agree closely with the calculated angles $c : (hhl)$ or $c : (\bar{h}hl)$. Thus the X-ray elements suit the geometrical observations well and, at the same time, the forms $a(100)$, $c(001)$, $m(110)$, $n(013)$, $d(101)$, $D(\bar{1}01)$, $r(1.1.10)$, $R(\bar{1}.1.10)$, $p(115)$, $P(\bar{1}15)$, $u(113)$, $U(\bar{1}13)$, $z(112)$, $q(111)$, $Q(\bar{1}11)$ are confirmed. We may accept Miers's statement that the common forms are $c m d D p P q Q$; and it seems proper to regard the forms $t T h H y Y \rho$ (table I) as uncertain.

In keeping with the Bravais principle, when the vertical axis is much longer than the other axes, crystals of xanthoconite are always more or less tabular parallel to the base, which is also the plane of cleavage; and the gnomonic distances h/l of the (hhl) planes are terms of an harmonic series (1937):

$$c(0) \quad r(\frac{1}{10}) \quad p(\frac{1}{5}) \quad u(\frac{1}{3}) \quad z(\frac{1}{2}) \quad q(1).$$

But in detail there are many exceptions to the theoretical habit required

in the space-group $F2/d$ by the Bravais–Donnay–Harker principle (Donnay, 1946).

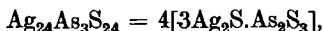
TABLE II. Xanthoconite: calculated and measured angles.

	Calculated.	Measured.
$ca = (001) : (100)$	$89^{\circ}29\frac{1}{2}'$	$88^{\circ}37' - 89^{\circ}41'$ M. A. P. (4)
$am = (100) : (110)$	62 37	62 18 - 62 32 M. A. P. (6)
$cm = (001) : (110)$	89 46	89 42 - 89 55 M. A. P. (4)
$cn = (001) : (013)$	$59 41\frac{1}{2}$	59 52 - 60 09 M. A. P. (2)
cd or cD	—	68 14 - 70 46 (17)
$cd = (001) : (101)$	$68 56\frac{1}{2}$	68 42 Miers 68 54 Miers
$cD = (001) : (\bar{1}01)$	69 50	69 30 Breithaupt 69 40 Streng 69 49 M. A. P. 69 57 Miers 70 01 Miers
cr or cR	—	28 18 - 31 32 (10)
$cr = (001) : (1.1.10)$	29 58	29 25 Schrauf 30 00 Schabus
$cR = (001) : (\bar{1}.1.10)$	$30 05\frac{1}{2}$	30 04 Schrauf 30 09 Miers
cp or cP	—	48 10 - 50 25 (25)
$cp = (001) : (115)$	49 00	48 57 Tokody 48 58 M. A. P. 49 02 Miers 49 03 Miers 49 04 M. A. P. 49 07 Streng
$cP = (001) : (\bar{1}15)$	$49 16\frac{1}{2}$	49 10 Schabus 49 10 Schrauf 49 10 Tokody 49 17 Miers 49 23 M. A. P.
$qu = (001) : (113)$	62 23	61 40 Tokody
$U = (001) : (\bar{1}13)$	$62 45\frac{1}{2}$	62 51 Tokody
$cz = (001) : (112)$	$70 42\frac{1}{2}$	70 28 Tokody
cq or cQ	—	70 03 - 81 30 (19)
$cq = (001) : (111)$	$79 57\frac{1}{2}$	79 25 Breithaupt 79 39 M. A. P. 79 59 Miers 80 01 Miers 80 08 M. A. P.
$cQ = (001) : (\bar{1}11)$	$80 24\frac{1}{2}$	80 26 M. A. P. 80 46 Miers

Figs. 1–3 illustrate the principal habits of xanthoconite. Fig. 1 represents the two crystals from Příbram, Bohemia (material no. 1), on which the goniometric and X-ray measurements were made. Fig. 2 is the typical habit of the so-called ‘rittingerite’ from Joachimsthal, which was shown to be xanthoconite by Miers (1893) aided by Prior. Fig. 3,

which shows elongation with the *b*-axis, is based on Miers's plan of crystals from Freiberg; the artificial crystals described recently (1947) have a similar habit.

Unit-cell contents and density.—The base-centred cell with dimensions $a' b' c' \beta'$, already given, contains



while the face-centred cell $a b c \beta$ has the double volume and cell content. The calculated density is 5.53, which affords striking verification of Prior's two sets of pyknetric determinations on 23 mg., which gave the specific gravities 5.68 and 5.40, average 5.54.

Optics and twinning.—The crystal used for X-ray measurements is yellow under the microscope, with no distinct pleochroism. It shows the emergence of a bisectrix nearly normal to the base and the optic axial plane normal to the symmetry plane. $2E$ is very large and the dispersion is very strong $r < v$. An entirely satisfactory determination of the sign was not obtained. In view of the very limited material no attempt was made to determine the refractive indices in melts of selenium and arsenic selenide, in which the crystals, like those of polybasite, would doubtless have dissolved. These observations confirm those of Miers, who also gave the optic sign as negative.

Miers also noted optical effects indicating twinning on (001). Our X-ray crystal showed little evidence for this under the microscope, but the Weissenberg photographs showed faint additional ($h0l$) spots exactly in positions required by twinning on (001). Evidently the crystal is in very small part twinned by reflection in the base, which is a plane of pseudo-symmetry in the F-lattice and consequently a probable plane of twinning.

X-ray powder pattern.—Samples from materials 1, 2, 3 all gave the same X-ray powder pattern. To aid in the identification of xanthoconite and perhaps eventually in the determination of the structure, the observations on the best film are given with the calculated spacings of the reflecting planes in table III.

PYROSTILPNITE.

Crystal lattice and morphology.—In view of the uncertainty of the crystallography of pyrostitlpnite—even the crystal system is doubtful—a determination of the crystal lattice was first made from X-ray photographs of a lath-shaped crystal from Příbram (material 4) rotated about the long edge of the lath. The simplest cell in the lattice is monoclinic,

space-group $P2_1/c$, with

$$a' = 6.83, b' = 15.81, c' = 6.23 \text{ kX}, \beta' = 117^\circ 09'.$$

The face of the lath is the symmetry plane, and the long edge is taken as the vertical axis, as in Luedecke's setting (1882). Fortunately the space-

TABLE III. Xanthoconite, $3\text{Ag}_2\text{S}\cdot\text{As}_2\text{S}_3$; Joachimsthal, Bohemia,
X-ray powder pattern.
Monoclinic, $F2/d$.

$$a = 11.97, b = 6.20, c = 31.82 \text{ kX}, \beta = 90^\circ 30'; Z = 8.$$

<i>I</i>	$\theta(\text{Cu})$	<i>d</i> (meas.)(<i>hkl</i>)	<i>d</i> (calc.)	<i>I</i>	$\theta(\text{Cu})$	<i>d</i> (meas.)(<i>hkl</i>)	<i>d</i> (calc.)	
2	8.05	5.49	$\begin{cases} (202) & 5.585 \\ (\bar{1}11) & 5.428 \\ (111) & 5.421 \end{cases}$	1	16.5	2.71	$\begin{cases} (\bar{2}22) & 2.714 \\ (222) & 2.710 \\ (\bar{3}17) & 2.709 \end{cases}$	
$\frac{1}{2}$	10.55	4.20	$\begin{cases} (\bar{1}15) & 4.172 \\ (115) & 4.155 \end{cases}$	$\frac{1}{2}$	17.0	2.63	$\begin{cases} (0.0.12) & 2.651 \\ (\bar{1}.1.11) & 2.565 \end{cases}$	
2	11.05	4.01	$\begin{cases} (\bar{2}06) & 3.986 \\ (008) & 3.977 \\ (206) & 3.952 \end{cases}$	$\frac{1}{2}$	17.45	2.56	$\begin{cases} (\bar{1}.1.11) & 2.556 \\ (\bar{2}26) & 2.447 \end{cases}$	
2	13.2	3.37	$\begin{cases} (\bar{3}11) & 3.339 \\ (311) & 3.334 \end{cases}$	1	18.2	2.46	$\begin{cases} (028) & 2.445 \\ (\bar{3}19) & 2.443 \\ (226) & 2.439 \end{cases}$	
3	14.2	3.13	(020) 3.100					
$\frac{1}{2}$	14.55	3.06	(022) 3.043					
			(400) 2.992					
			($\bar{1}$ 19) 2.980	1	20.15	2.23	$\begin{cases} (\bar{1}.1.13) & 2.240 \\ (\bar{1}.1.13) & 2.233 \end{cases}$	
10	14.9	2.99	$\begin{cases} (\bar{3}15) & 2.977 \\ (119) & 2.969 \\ (\bar{3}15) & 2.959 \end{cases}$				$\begin{cases} (\bar{5}11) & 2.229 \\ (\bar{5}11) & 2.226 \\ (0.2.10) & 2.220 \end{cases}$	
			($\bar{2}.0.10$) 2.820				(420) 2.153	
			(404) 2.809				(422) 2.135	
6	15.85	2.81	$\begin{cases} (\bar{2}.0.10) & 2.801 \\ (404) & 2.793 \end{cases}$	3	21.12	2.13	$\begin{cases} (\bar{4}22) & 2.132 \\ (\bar{2}.0.14) & 2.131 \\ (\bar{2}.0.14) & 2.118 \end{cases}$	
<i>I</i>	$\theta(\text{Cu})$	<i>d</i> (meas.)	<i>I</i>	$\theta(\text{Cu})$	<i>d</i> (meas.)	<i>I</i>	$\theta(\text{Cu})$	<i>d</i> (meas.)
1	21.6	2.09	$\frac{1}{2}$	27.0	1.693	$\frac{1}{2}$	33.95	1.376
2	22.85	1.980	$\frac{1}{2}$	27.85	1.645	$\frac{1}{2}$	37.25	1.270
$\frac{1}{2}$	23.65	1.916	$\frac{1}{2}$	28.7	1.601	$\frac{1}{2}$	39.1	1.219
1	24.25	1.872	$\frac{1}{2}$	29.8	1.547	$\frac{1}{2}$	40.0	1.196
$\frac{1}{2}$	24.95	1.823	$\frac{1}{2}$	31.1	1.488	$\frac{1}{2}$	43.6	1.115
2	25.8	1.766	$\frac{1}{2}$	31.8	1.459			

group is uniquely determined by the missing reflections, thus establishing the monoclinic prismatic class and excluding orthorhombic symmetry, which is geometrically possible, and triclinic symmetry, which has been suggested in Dana (1944). As shown by old and new goniometric observations, crystals of pyrostilpnite are geometrically "orthorhombic" with indistinguishable (*hkl*) and ($\bar{h}kl$) forms. It seems best, therefore, to take the equivalent lattice cell which has $a = [201]$, $b = [010]$, $c = [001]$, and the space-group symbol $B2_1/c$. This cell has the following dimensions¹ with which are compared Professor Murdoch's cell dimensions obtained on a crystal from Randsburg (material no. 6):

$$a = 12.15, b = 15.81, c = 6.23 \text{ kX}, \beta = 90^\circ 00' \text{ (M. A. P.)}$$

$$a = 12.2, b = 15.87, c = 6.28 \text{ kX}, \beta = 90^\circ \pm 30' \text{ (J. M.)}$$

¹ In Å. the unit-cell dimensions of pyrostilpnite are $a' = 6.84$, $b' = b = 15.84$, $c' = c = 6.24$ (M. A. P.); $a = 12.2_2$, $b = 15.90$, $c = 6.29$ (J. M.).

The rectangular cell dimensions for the crystal from Příbram give the following geometrical ratios which only roughly resemble the presently accepted elements of Luedecke (1882) when these are appropriately transformed:

$$a : b : c = 0.7685 : 1 : 0.3941, \beta = 90^\circ 00' \text{ (M. A. P., X-ray)}$$

$$2a : b : 2c = 0.7094 : 1 : 0.3564, \beta = 90^\circ 00' \text{ (Luedecke).}$$

This unsatisfactory comparison is due to the fact that Luedecke's fundamental angles are those of forms which he denotes as (191) and ($\bar{1}91$); our subsequent goniometric work shows that these forms are in fact (181) and ($\bar{1}81$) in Luedecke's notation, or (141) and ($\bar{1}41$) in ours. Luedecke's fundamental angles then compare tolerably with the angles calculated on our lattice:

Luedecke.	M. A. P. (calc.)
$oo = (191) : (\bar{1}91) = 110^\circ 11' *$	$ss = (141) : (\bar{1}41) = 109^\circ 02'$
$oo = (191) : (\bar{1}91) = 29 \text{ } 46\frac{1}{2} *$	$ss = (141) : (\bar{1}41) = 30 \text{ } 43$

Crystals of pyrostitpnite are all small laths or plates flattened on (010) and striated parallel to $[10\bar{1}]$ and sometimes also to $[101]$. The forms other than $b(010)$ are all represented by narrow faces in the zone $[001]$ and the geometrically equivalent zones $[10\bar{1}]$ and $[101]$. The reflections are generally poor and only the smallest crystals are unwarped.

Table IV summarizes two-circle measurements on eleven crystals from Randsburg (material no. 6), by Professor Murdoch, and two

TABLE IV. Pyrostitpnite: calculated and measured two-circle angles.

	Calculated.		Measured.	
	ϕ	ρ	ϕ	ρ
$b(010)$	0°00'	90°00'	0°00'	90°00' *
$k(230)$	40 56	90 00	41 16	90 00 (4) J. M.
$m(210)$	68 59	90 00	70 19	90 00 † J. M.
			69 35	90 00 (6) M. A. P.
$p(111)$	52 27½	32 53½	52 22	33 08 (2) J. M.
$q(121)$	33 03	43 14	33 01	43 50 † J. M.
			32 52	43 35 (4) M. A. P.
$r(131)$	23 27	52 11	25 20	50 18 (1) J. M.
			23 19	52 07 (8) M. A. P.
$s(141)$	18 01	58 54	18 28	59 (1) J. M.
			18 10	58 37 (1) M. A. P.
$t(151)$	14 35	63 50½	14 30	64 28 (4) J. M.

* On all crystals.

† On all Murdoch's crystals.

crystals from Andreasberg (material no. 5), shown in figs. 4 and 5, and compares the angles with those calculated from the elements of the rectangular lattice cell. From both sets of measurements a few single

poor readings requiring complex indices have been omitted as insignificant. The comparison shows that the X-ray elements are satisfactory and it establishes the forms listed.

Table V correlates Luedecke's measurements, omitting some redundant angles, with corresponding calculated angles on our elements. In view of the initial error mentioned above it is not surprising that the comparison is generally poor; but the angles do serve to establish the forms $b(010)$, $m(210)$, $s(141)$, $S(\bar{1}41)$, $p(111)$, $d(101)$, $D(\bar{1}01)$ in our notation. The forms (120), (110), (121) do not seem to be well supported, and the forms (100) (no angles) and (001) (not figured) also need confirmation. The following list correlates Luedecke's notation with ours. The forms with letters (J. M. and M. A. P.) are regarded as established, those without letters as uncertain. Since positive and negative forms cannot be distinguished we must assume each observed form (hkl) implies the corresponding form ($\bar{h}kl$).

J. M. & M. A. P.	$-(100)$	$b(010)$	$-(001)$	$-(120)$	$k(230)$	$-(110)$	$m(210)$
Luedecke	$a(100)$	$b(010)$	$c(001)$	$\delta(140)$	—	$s(120)$	$m(110)$
J. M. & M. A. P.	$d(101)$	$D(\bar{1}01)$	$p(111)$	$P(\bar{1}11)$	$q(121)$	$Q(\bar{1}21)$	$r(131)$
Luedecke	$d(101)$	$d'(\bar{1}01)$	$\pi(121)$	$\pi'(\bar{1}21)$	$p(141)$	$p'(\bar{1}41)$	—
J. M. & M. A. P.	$R(\bar{1}31)$	$s(141)$	$S(\bar{1}41)$	$t(151)$	$T(\bar{1}51)$		
Luedecke	—	$o(191)$	$o'(\bar{1}91)$				
			$\dots (181) = (\bar{1}81)$				

TABLE V. Pyrostitpnite: interfacial angles.

Calculated (M. A. P.).		Measured (Luedecke).
$bm = (010) : (210)$	$68^{\circ}59'$	$bm = 70^{\circ}56'$ (8)
		$69\ 13\frac{1}{2}$ (1)
$(010) : (120)$	$33\ 03$	$b\delta = 36ca$ (5)
$(010) : (110)$	$52\ 27\frac{1}{2}$	$bs = 54\ 49$ (5)
$bs = (010) : (141)$	$35\ 29$	$bo = 35\ 39$ (5)
		$35\ 00$ (1)
$bS = (010) : (\bar{1}41)$	$35\ 29$	$bo' = 35\ 02$ (1)
$bq = (010) : (121)$	$54\ 57\frac{1}{2}$	$bp = 57\ 32$ (1)
$bp = (010) : (111)$	$70\ 40\frac{1}{2}$	$b\pi = 71\ 07$ (1)
$dD = (101) : (\bar{1}01)$	$54\ 18$	$dd' = 54\ 23$ (1)
$cd = (001) : (101)$	$27\ 09$	$cd = 26\ 30$ (1)

Despite the generally poor development of pyrostitpnite crystals it is interesting to find a fair agreement between the actual form development and that required by the Bravais-Donnay principle, according to which the importance of a crystal form is proportional to the spacing of the corresponding lattice planes in the notation appropriate to the space group. The lack of a straightforward explanation of this empirical approximation has led to some disbelief in the actuality of the relationship, and therefore another example may not be superfluous. Occa-

sionally, as in muscovite (Peacock & Ferguson, 1943, p. 77), there is almost perfect agreement between the occurrence and statistical importance of the forms of a crystal species and the sequence of lattice planes in order of decreasing spacings; more often, as in axinite (Peacock, 1939, p. 98), the well-established forms tend to appear at the head of the list without close proportionality between form importance and spacing.

Table VI lists the first 34 sets of lattice planes of pyrostitlpnite in order of descending spacings, the indices (hkl) being in the form appro-

TABLE VI. Pyrostitlpnite: theoretical and actual form development.

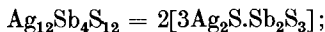
(hkl)	d (kX)	Form.	(hkl)	d (kX)	Form.	(hkl) ¹	d (kX)	Form
(020)	7.91	b	(311)	3.32	—	(022)	2.90	—
(200)	6.08	?	($\bar{3}$ 11)	3.32	—	(331)	2.85	—
(210)	5.67	m	(240)	3.31	?	($\bar{3}$ 31)	2.85	—
(111)	5.23	p	(141)	3.22	s	(420)	2.84	(m)
($\bar{1}$ 11)	5.23	P	($\bar{1}$ 41)	3.22	S	(250)	2.81	—
(220)	4.82	?	(321)	3.12	—	(202)	2.77	d
(121)	4.54	q	($\bar{3}$ 21)	3.12	—	($\bar{2}$ 02)	2.77	D
($\bar{1}$ 21)	4.54	Q	(002)	3.12	?	(151)	2.75	t
(230)	3.98	k	(012)	3.06	—	($\bar{1}$ 51)	2.75	T
(040)	3.95	(b)	(400)	3.04	(?)	(212)	2.73	—
(131)	3.82	r	(410)	2.98	—	($\bar{2}$ 12)	2.73	—
($\bar{1}$ 31)	3.82	R						

priate to the space-group $B2_1/c$: (hkl) only with $h+l$ even; ($0k0$) only with k even; ($h0l$) only with h even and l even. The first 13 places correspond to known forms (including two which were not well established goniometrically), with (020) in first place in keeping with the prime importance of b as a form and cleavage; and the next 20 places account for the 10 remaining forms, including doubtful ones and, of course, repetitions such as (m)(420) which first appeared as m (210). This is perhaps an average case, in which the agreement between theoretical and actual form development is far from perfect, but still quite good enough to lead the morphologist to the correct crystal lattice (axial ratios and centring) and often to the correct possible space groups.

Figs. 4 and 5 picture the two measured crystals of pyrostitlpnite from Andreasberg, which measure 0.17×0.27 mm. and 0.10×0.28 mm. in cross-section, respectively. The first of these crystals is apparently a single individual, with a small attached plate in parallel position, and the monoclinic symmetry is emphasized by the unequal development of the forms r q as compared to the geometrically equivalent forms R Q . The second crystal is a twin group in which the principal parts are best described as twinned on the c -axis with composition plane b . Again

the monoclinic symmetry is shown by the unequal development of geometrically equivalent forms and by the striations on b which follow $[10\bar{1}]$ but not $[101]$. These appearances speak, of course, for the simplest cell in the lattice ($P2_1/c$), but the rectangular cell is the only practical one since positive and negative forms cannot be distinguished.

Cell contents and density.—The simplest (P) cell with the dimensions $a' b' c' \beta'$ contains



the rectangular (b) cell $a b c \beta$ has twice the volume and cell contents. The calculated density is 5.97, confirming the specific gravity 5.94 measured on 6 mg. by Berman (Dana, 1944, p. 369), who suspected that the value 4.3 (Luedecke) was low.

Optics and twinning.—Flat-lying laths of pyrostitilpnite are orange-yellow under the microscope and they mostly fail to extinguish completely in any position of the stage. Occasional very thin tips do extinguish at 8–11° to the c -axis and in rare cases symmetrical extinction about the c -axis is noted in twinned plates. The twin law is best defined as, twin axis $[001]$, composition surface (100) or (010), usually the latter, as in orthoclase. Twinned plates joined on (010) would, of course, give the observed lack of extinction. The orientation noted is $Y = b[010]$, $X : c[001] = 8\text{--}11^\circ$, as in Dana (1944); the sign could not be definitely determined.

X-ray powder pattern.—The pattern of pyrostitilpnite is quite distinct from that of xanthoconite. The numerical data are given in table VII.

TABLE VII. Pyrostitilpnite, $3\text{Ag}_2\text{S.Sb}_2\text{S}_3$; Příbram, Bohemia.
X-ray powder pattern.

Monoclinic, $B2_1/c$.							
$a = 12.15, b = 15.81, c = 6.23 \text{ kX}; \beta = 90^\circ 00'; Z = 4.$							
I	$\theta(\text{Cu})$	$d(\text{meas.})(hkl)^*$	$d(\text{calc.})$	I	$\theta(\text{Cu})$	$d(\text{meas.})(hkl)^*$	$d(\text{calc.})$
$\frac{1}{2}$	5.5	8.02 (020)	7.905	5	18.5	2.42 { (260)	2.417
$\frac{1}{2}$	7.1	6.22 (200)	6.075			{ (440)	2.408
$\frac{1}{2}$	7.7	5.74 (210)	5.671	$\frac{1}{2}$	19.3	—	—
1	13.4	3.32 { (311)	3.320	$\frac{1}{2}$	19.8	2.27 (242)	2.270
		{ (240)	3.313			{ (521)	2.176
$\frac{1}{2}$	13.8	3.22 (141)	3.218	$\frac{1}{2}$	20.7	2.17 { (402)	2.175
		{ (321)	3.120	1	21.4	2.11 (270)	2.117
2	14.3	3.11 { (002)	3.115			{ (422)	2.097
		{ (012)	3.056	1	21.6	2.09 { (171)	2.092
$\frac{1}{2}$	14.7	3.05 { (400)	3.038			{ (123)	1.982
$\frac{1}{2}$	14.9	2.99 (410)	2.983	$\frac{1}{2}$	22.9	1.975 { (080)	1.976
		{ (331)	2.854			{ (240)	1.890
10	15.7	2.84 { (420)	2.835	5	{ 24.0	1.890 (630)	1.890
		{ (151)	2.747		{ 24.2	1.875 { (280)	1.879
$\frac{1}{2}$	16.3	2.74 { (212)	2.730		{ 25.0	1.875 { (351)	1.867
		{ (060)	2.635	2	{ 25.3	1.819 (143)	1.818
5	16.9	2.64 { (430)	2.632			{ (640)	1.802
						{ (323)	1.799

* $(\bar{h}kl)$ is not listed since it has the same spacing as (hkl) .

Relation of xanthoconite to pyrostitlpnite.—The rectangular multiple lattices of the two minerals show the following close metrical similarities:

Xanthoconite.	Pyrostitlpnite.
$a = 11.97 \text{ kX}$	$a = 12.15 \text{ kX}$
$b = 6.20$	$c = 6.23$
$c = 31.82$	$2b = 31.62$
$\beta = 90^\circ 30\frac{1}{2}'$	$\beta = 90^\circ 00'$
Space group $B2_1/c$	Space-group $F2/d$

However, the relation is not a direct analogy, nor can the cell edges be renamed to produce direct correspondence. In xanthoconite the plane of tabular development and cleavage is perpendicular to the symmetry plane; in pyrostitlpnite the plane of platy development and cleavage is parallel to the symmetry plane. This indirect relation was already correctly inferred by Miers (1893, p. 215).

Pyrostitlpnite provides another example of the frequent situation in which the lattice (simple or multiple) of a crystal with the symmetry of a particular system is metrically indistinguishable from the lattice typical of a system of higher symmetry. It is really not important whether β is a few minutes off 90° or whether the angle will change a few minutes with change of temperature. The fact is that β is practically indistinguishable from 90° and we are obliged to describe a crystal with rectangular axes as monoclinic. I still find this unsatisfactory and most students find it absurd. No doubt we shall continue this usage, recognizing that the crystal systems are symmetry systems and putting up with the present system names where they lead to self-contradiction; but for didactic purposes, and perhaps in the long run for general use, it seems reasonable to suggest a set of names for the symmetry systems which is in line with the international symmetry notation and involves only a few new self-explanatory terms. Such a proposal is made in a more extended discussion now in press (1950). The names and symbols suggested for the symmetry systems, followed by the names of the normal lattice types, are: monogonal (1) (triclinic), digonal (2) (monoclinic), tri-digonal (222) (orthorhombic, rectangular), trigonal (3) (rhombohedral or hexagonal), tetragonal (4) (tetragonal, quadratic), hexagonal (6) (hexagonal), tetra-trigonal 4(3) (cubic).

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