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Xanthoconite and Rittingerite, with remarks on the Red Silvers.

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[Read January 17th, 1893.]

Literature relating to Xanthoconite and Rittingerite.

1. 1840. Breithaupt, *Journal für praktische Chemie*, XX., 67.
2. 1845. Breithaupt, *Poggendorf, Annalen*, LXIV., 272.
3. 1845. Plattner ,, ,, ,, 275.
4. 1852. Zippe, *Sitzungsberichte Akad. Wien*, IX., 345.
5. 1866. Weisbach, *Berg-und Hütten-männische Zeitung*, XXV., 54.
6. 1872. Schrauf, *Sitzungsberichte Akad. Wien*, LXV., 227.
7. 1874. Frenzel, *Mineralogisches Lexicon Sachsen*, 348.
8. 1878. Streng, *Neues Jahrbuch*, 917.
9. 1879. Schrauf, ,, ,, 144.
10. 1879. Streng, ,, ,, 547.
11. 1879. Becke, *Tschermak, Mineralogische Mittheilungen*, II., 94.
12. 1886. Streng, *Neues Jahrbuch* (1), 57.

CONTENTS.

I. HISTORICAL SKETCH.

(*A*). *Xanthoconite.*—The name xanthoconite was given by Breithaupt (1) to a mineral which he found in 1840 associated with proustite upon an old ore-specimen in the collection of the Berg-Akademie at Freiberg. He describes it as occurring in reniform masses with a surface consisting of microscopic crystals, but with a crystalline granular interior. The crystals appeared to be either acute rhombohedra or a combination of a rhombic prism with a hemidome; H = 2 – 3; Sp. Gr. = 4·112 – 4·159. Plattner could find only silver, arsenic and sulphur, with a minute trace of iron; the silver assay gave 59·1 per cent. This specimen was from the Himmelsfürst mine at Erbisdorf, near Freiberg, and was raised in 1797.

Five years later in the same mine Breithaupt himself (2) found another variety of the mineral occurring in thin tabular crystals in calcite. Only one specimen was found. The measurement of the broken fragments of an apparently hexagonal plate led him to the conclusion that the crystals were a combination of the basal plane with two rhombs, having their even cleavage parallel to one of the rhombohedrons and to the basal plane; H = 2¼ – 3¼; Sp. Gr. = 5·078 – 5·166; a new determination of the material originally described, after it had been carefully purified from intermixed "Silberschwärze," gave Sp. Gr. = 5·158 – 5·191.

These two varieties of xanthoconite are distinguished by a difference in colour; the original mineral was dark cochineal-red to clove-brown in the mass, and orange-yellow in the thinnest crystals, with a glistening streak of a dark orange-yellow inclined to yellowish-brown colour; the second specimen was orange-yellow, with a streak between orange-yellow and yellowish-brown, somewhat darker than the superficial colour.

Analyses of both these specimens were made by Plattner (3), who found for the brown variety (using 0.5 gram)

Ag = 64·181
S = 21·358
Fe = 0·970

(whence by difference As = 13·491). An independent assay gave 64·2 per cent. of silver.

Of the yellow variety there was only sufficient material for the determination of the sulphur in the wet way, the silver being estimated by the blowpipe. The numbers obtained were :—

Ag = 63·880
S = 21·798

(whence by difference As = 14·322).

This variety contained no iron.

The formula deduced by Plattner from these analyses is

$$3Ag_2S. As_2 S_5 + 2\ [3Ag_2 S. As_2 S_3].$$

Xanthoconite was thus made to represent a new type in mineralogy, no *sulph-arsenate* having been previously described.

Twenty-one years later Weisbach (5) mentions the further occurrence of this very rare mineral at the Himmelfahrt mine in 1860, and at the Gesegnete Bergmanns Hoffnung mine in 1864. One interesting observation of this author seems to have escaped the notice which it deserved: he found an isolated crystal on one of the specimens having the appearance of a rhombic prism combined with a hemidome, and suggested that xanthoconite may be in reality a hemi-rhombic mineral.

Frenzel (7) mentions other mines in the Freiberg district which have yielded xanthoconite.

(*B*). *Rittingerite.* This mineral was first described by Zippe (4) in 1852, as occuring in minute crystals with proustite from Eliaszeche mine, Joachimsthal.

Schabus, who measured the crystals, found them to be rhombic-shaped tables belonging to the monosymmetric system, the plane of symmetry being parallel to the shorter diagonal (see fig. 5); there was a cleavage parallel to the plane of the plates; $H = 2\frac{1}{2} - 3$; lustre metallic-adamantine; colour dark honey-yellow inclined to hyacinth-red; streak orange-yellow. The material was insufficient for analysis, but blowpipe tests showed the presence of silver and arsenic.

Zippe remarks that the mineral differs from proustite in colour and streak, and suggests that it has a different chemical composition, but that it may bear the same relation to fireblende that proustite does to pyrargyrite; he distinguishes it from xanthoconite on account of the crystalline system, colour and inferior transparency.

Twenty years later Schrauf published an elaborate memoir on similar crystals from Joachimsthal, dispersed on the pseudomorphous sulphide described by Tschermak under the name "Silberkies" (*Sitzungsber. Akad. Wien*, LIV. (1) 342).

With material weighing 0·0045 gram Schrauf determined the specific gravity to be 5·63, and the percentage of silver (by reduction on charcoal) to be 57·7. Besides the silver he found arsenic, but failing to obtain any clear indications of sulphur, and thinking that he recognised the characteristic smell of selenium when the mineral was heated, he concluded that rittingerite is a compound of silver, arsenic and selenium.

This author's crystallographic observations, which lead to results differing somewhat from those of Schabus, will be discussed below. It is sufficient to say here, that the plane angle of the rhombic plates (which should be 126°18′ according to Schabus) was determined by Schrauf to be 124° 20′ by means of microscopic measurements.

Streng (8) in 1878, described as fireblende some small crystals with the habit of stilbite and of a hyacinth-red colour occurring upon pyrargyrite, and associated with proustite, from the Dolores I. mine, Chañarcillo.

Schrauf (9), however, in the following year pointed out that Streng's measurements agreed very closely with his own measurements of rittingerite, and suggested that the Chañarcillo mineral should be referred to that species.

Streng (10) confessed that the angles were the same, but pointed out that there is a striking similarity between certain angles in rittingerite, xanthoconite and fireblende. He found by blowpipe tests that the Chañarcillo mineral contained *sulphur* and silver, and therefore concluded that it could not be identical with Schrauf's rittingerite, which contained selenium and no sulphur.

Seven years later, however, Streng (12) proved by micro-chemical reactions, both in the Chañarcillo mineral and in the rittingerite from Joachimsthal, the presence of silver, arsenic and sulphur, and failed to recognise selenium in either.

Becke (11) had previously, in 1879, noted the occurrence, at Schemmitz, of minerals which he describes as rittingerite and fireblende, but stated that the latter yielded silver and *arsenic* (!).

II. SUMMARY OF RESULTS.

From the above survey xanthoconite and rittingerite appear to be two fairly well defined species, and accordingly we find them so described in the text-books.

Xanthoconite is stated to be a sulph-arsenate, containing about 64 per cent. of silver, having a specific gravity about 5·2, and crystallising in the rhombohedral system.

Rittingerite is generally regarded as a compound of silver, arsenic and selenium, containing about 58 per cent. of silver, having a specific gravity about 5·6, and crystallising in rhombic tables belonging to the monosymmetric system.

On the other hand, when the data are criticised more closely it is seen that, as regards xanthoconite, some doubt is thrown upon the crystalline form by the observation of Weisbach, while in the case of rittingerite the composition is left uncertain owing to the micro-chemical examination of Streng. It will appear in the course of the following investigation that neither of these minerals has yet been correctly determined in respect of composition, form or physical characters.

Now it is only necessary to examine the two minerals under the microscope to see that they are remarkably similar in most respects.

In the following pages it will be shown that xanthoconite and rittingerite are one and the same mineral; that this mineral has the percentage composition of proustite, but differs completely from that species in physical and morphological characters; and that it is isomorphous with fireblende, and bears the same relation to proustite which fireblende bears to pyrargyrite.

The observations will be described in considerable detail, for the material is not all that could be desired for accurate measurement and analysis: consequently we have to show in the first place that the characters of the two minerals, even if only approximately determined, are identical within the limits of error, and then, by combining the best from all the observations made on both varieties, to deduce the best possible constants for the species.

III. DESCRIPTION OF XANTHOCONITE.

(*a.*) *Modes of occurrence and associations.*—The collection of the British Museum contains about thirty specimens of this mineral from the following localities: Freiberg, Johanngeorgenstadt, Markirch, Rudelstadt and Chañarcillo.

The majority of the specimens from Freiberg were acquired recently for the purpose of the present investigation.

The xanthoconite from these localities presents such differences of appearance that a short description of each is necessary.

Freiberg.—Among the specimens in the British Museum there is nothing which resembles the reniform crystalline-granular and brownish material described by Breithaupt and analysed by Plattner; they all agree more nearly with that described by Breithaupt in 1845, as yellow tabular crystals occurring in calcite. Among these, at least three types are to be distinguished.

(1.) Small round masses, consisting of an aggregation of minute orange-yellow tablets, like fig. 3.

(2.) Stout tabular crystals with striated sides, somewhat resembling hexagonal plates with bevelled edges like those of the tabular Freiberg stephanite; these are always composed of irregularly grouped plates intergrown in nearly parallel positions; fig. 3.

(3.) Isolated thin plates resembling fireblende in habit, see figs. 1, 9.

The colour of all these crystals is usually a dull orange to brownish-yellow, but on some specimens of the second and third types they are of a rich vermilion-red very nearly identical with that of proustite.

In thin splinters all exhibit the same lemon-yellow colour by transmitted light, and the streak is the same :—clear orange-yellow for all.

One specimen which appears to be identical with the remainder is labelled as from Siebenlehn, Nassau-Freiberg. On the Freiberg specimens the xanthoconite is sparsely dispersed upon calcite, together with brilliant scalenohedral crystals of proustite; the specimens occasionally show decomposing marcasite somewhat resembling the silberkies with which rittingerite is associated at Joachimsthal; also stephanite, argentite and the decomposition products of cobalt and nickel ores.

The xanthoconite itself is always situated in isolated crystals or groups upon the calcite, sometimes also in the form of very thin scales filling cavities in the calcite; it is contemporaneous with the proustite, and I have never observed the paragenesis mentioned by Breithaupt, who speaks of proustite occurring upon xanthoconite.

One specimen alone differs somewhat from the others; the xanthoconite here occurring in irregular rhombic tables upon the corroded surface of crystallised argentite.

Johanngeorgenstadt.—One specimen from this locality shows xanthoconite in rhombic plates, having a habit like that of the Joachimsthal rittingerite, of a brownish-yellow colour, dispersed on vein-quartz with proustite, argentopyrite (in small crystals) and a little calcite.

Rudelstadt.—Two specimens from this locality present the mineral in a yellow-brown earthy form disseminated in calcite which veins massive arsenic.

Markirch, Elsass.—This occurrence has not been previously described. The crystals were noticed by myself in the recesses of a fine specimen of proustite where they were almost concealed by other minerals.

The xanthoconite occurs in brilliant striated orange-yellow crystals whose projecting corners somewhat resemble rhombohedra of chalybite; they are situated on pearlspar and are accompanied by fine prisms of proustite and crystallised calcite, overlying botryoidal arsenic; here again the mineral appears to be contemporaneous with the proustite.

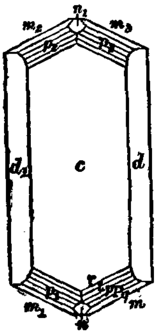
I have noticed xanthoconite from this locality in the Berlin Museum f. Naturkunde, and other examples will doubtless be found if search be made among the older specimens of proustite from Markirch (Sainte Marie-aux-Mines).

The habit of the crystals is quite peculiar, see fig. 2. p. 194, and they are much larger than those from Freiberg. It will be seen below that these crystals are all-important as establishing the symmetry of the mineral.

Chañarcillo, Chili.—The crystals from this locality appear to be of the same habit as the Markirch xanthoconite. They are stout orange-yellow composite crystals occurring with prisms of proustite upon crystallised calcite. A beautiful specimen was acquired by the British Museum in 1881; I have found a magnificent crystal of the same habit, no less than 2 mm. in diameter, in a cavity between crystals of calcite on a specimen of proustite from the mine Dolores I. This crystal could only be made clearly visible by removing one side of the specimen. The mineral examined by Streng was from the same mine, and there is not the least doubt that it was xanthoconite.

(*b*). *Crystalline Form.*—This is generally supposed to have been determined by Breithaupt, but in reality his measurements only relate to a tabular crystal which broke to pieces in his fingers, so that he was only able to measure fragments; moreover, the reflecting surfaces were so bad that he was compelled to use the sun as a distant signal, and he expressly states that the angles cannot be relied upon to less than a degree. Such a determination is obviously almost valueless. It is difficult to understand how Breithaupt ever imagined the crystals to be hexagonal; they generally either resemble rhombic tables or are thin plates like those of fireblende. Weisbach, as we have seen, suggested that the mineral may be really hemi-rhombic. The optical characters are sufficient to show at a glance that it cannot be hexagonal.

The measurements of Streng will be discussed below. The measurements which I have been able to make relate to ten crystals from Freiberg,



Fg. 1.

and two from Markirch. All the best readings are given in the following table, and all the faces indicated by definite reflections, whether good or bad, are mentioned. The letters refer to fig. 1, which gives a general survey of the crystals; they are *all* fragments, and are supposed to be orientated as in fig. 1; p' is parallel to p, p_1' to p_1, &c.; a is a face nearly perpendicular to c on the right of the figure.

No account is here taken of a vast number of imperfect or striated faces which yielded indefinite or banded images. Those readings which are really excellent are marked with an asterisk.

Crystal 1. Determinable faces, $c\ p\ t\ d\ a\ a'\ c'\ d'\ d_1'\ n_1'\ q_2'$
$ac = 90°20'$ $ct = 36°46'$
$c'q_2' = 80°46'$ $cn_1' = 119°51'$

Crystal 2. Determinable faces, $c\ c'\ t\ p_1\ n_1'$
$c'\ n_1' = 59°52'$ or $60°20'$.

Crystal 3. Determinable faces, $c\ p\ d\ \ c'\ d_1'\ q_2'$
$cd = 69°12'$ to $69°33'$ $cq_2' = 100°26'$
$cp = 41°11'$.

Crystal 4. Determinable faces, $c\ a\ m\ m_1\ c'd_1'\ p_3'$
$c'd_1' = 69°29'$ * $a\,m = 62°28'$
$c'm = 90°35'$ * $m\ m_1 = 55°7'$
* $cm_1 = 90°8'$.

Crystal 5. Determinable faces, $c\ t\ P\ d\ c'\ p_2'\ d_1'$
$cP = 49°31'$
$Pd_1' = 85°19'$
$c'd_1' = 69°24'$.

Crystal 6. Determinable faces, $c\ m$ (2 faces $m_\alpha\ m_\beta$) $m_1\ d\ n_3'\ c'\ p_3'$
$cm_\alpha = 89°55'$ $cm_1 = 86°38'$ $c'd = 109°46'$
$c'm_\beta = 89°24'$ * $mm_1 = 55°3'$.

Crystal 7. Determinable faces, $c\ d\ q_2\ q_3$
$cq_3 = 79°3'$ or $79°59'$
$cd = 69°15'$ or $69°57'$
* $dq_3 = 61°2'$.

Crystal 8. Determinable faces, $c\ a\ m\ Pr_1\ p_1\ d_1\ c'\ d_1'\ t_2'\ p_2'\ n_1'$
$cd_1' = 70°46'$
$c'a = 90°22'$
$am = 62°32'$.

Crystal 9. Determinable faces, $c\ d\ d_1'$
$cd = 68°42'$ $d\ d_1' = 41°22'$.

Crystal 10. Determinable faces, $c\ q$
$cq = 77°1'$.

From the above measurements it is clear that the xanthoconite from Freiberg is not hexagonal, but is either orthorhombic or monosymmetric; the crystals are not sufficiently perfect to disclose the symmetry by their angular relations alone, but the optical characters show them to be monosymmetric since a bisectrix emerges nearly normal to *c*, but slightly inclined thereto in the plane containing the normals of *c a d*. Further, the optical characters show the plates to consist of twinned crystals which overlap. This twinning accounts for the appearance of the orthodome *d* at both the upper and lower ends of crystals 1, 3, 5, 9.

The axial angle *a c* may be calculated from the very perfect measurements, $cm = 90°8'$ and $am = 62°28'$, of crystal 4, which give $ac = 89°42\frac{3}{4}'$, showing that xanthoconite may be referred to three very nearly rectangular axes.

Now, owing partly to the twinning and partly to the imperfections of the faces on these crystals, it is impossible to say whether the various pyramids lie within the acute or the obtuse axial angles, so that we are compelled as a first approximation to take the axes as rectangular.

The angles and indices are then as follows:—

a 100	*q* 551	*h* 334
c 001	*d* 501	*n* 053
m 110	*t* 223	
P 111	*r* 112	

$$a : b : c = 1{\cdot}921 : 1 : 1{\cdot}034$$
$$\beta = 90°0'$$

		Observed.		Limits.	No.	Calculated.	
		°	'	° ' ° '		°	'
a m	100 : 110	62	30	62 28—62 32	2	—	
m m	100 : $\bar{1}$10	55	5	55 3—55 7	2	55	0
c d	001 : 501	69	37	68 42—70 46	9	—	
c h	001 : 334	41	11		1	41	9
c t	001 : 223	36	46		1	37	51
c P	001 : 111	49	31		1	49	32½
c q	001 : 551	79	17	77 1—80 46	5	80	16
c a	001 : 100	90	21	90 20—90 22	2	90	0
c m	001 : 110	90	0	89 24—90 35	4	90	0
c n	001 : 053	60	4	59 52—60 20	3	59	52½
P d	111 : 50$\bar{1}$	85	19		1	84	10½
d q	501 : 551	61	2		1	60	57
d d	501 : 50$\bar{1}$	41	22		1	40	46

The correct interpretation of these measurements is to be found in the table of calculated angles on p. 212.

It is clear that the two angles measured by Breithaupt, namely 69°30′ and 79°25′, are the angles *cd* and *cq*, and that his measurements were very near the truth; a combination of *cqd* would perhaps somewhat resemble a combination of basal plane with two rhombohedra in a crystal belonging to the second type.

We have now to compare with the above the results obtained from a small group removed from the Markirch specimen; this group consists of two crystals (fig. 2) united in twin position, the faces $c\ c_1$ being nearly parallel.

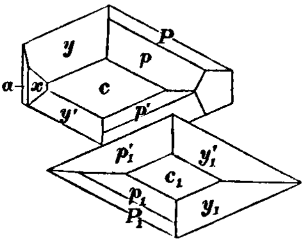


FIG. 2.

$c\,y = 57°19'$
$c\,p = 48°27'$
$c\,P = 49°28'$
$c\,p' = 47°59'$
$c\,x = 74°49'$
$c\,\alpha = 88°37'$
$c\,a = 89°41'$
$c\,d = 70°17'$

$*c_1\,y_1 = 56°9'$
$c_1\,y_1' = 55°55'$
$*c_1\,p_1 = 48°10'$
$c_1\,P_1 = 49°17'$
$*c_1\,p_1' = 48°36'$
$*p_1\,p_1' = 83°7'$
$p_1\,y_1 = 43°32'$

These measurements evidently belong to the same mineral as the Freiberg crystals, and they supply the indications of geometrical symmetry which are wanting in the latter. The crystals are seen to be referable to an oblique pyramid with a rhombic base of about 55°, and the plane of symmetry is parallel to the longer diagonal of the base; they prove distinctly that the mineral is twinned in such a manner that two crystals are united in reverse position with the *c* faces nearly parallel; and they show that there are two distinct forms *p P* inclined to *c* at angles of about 48¼° and 49½° respectively; both these faces are present upon the Freiberg crystals.

Referred to axes similar to those employed above, the indices and corresponding angles are—

p	111	*y*	$\bar{4}43$
c	001	*d*	501
P	21.21.20	*x*	701
a	100		

$$a : b : c = 1{\cdot}936 : 1 : 1{\cdot}003$$
$$\beta = 90°0'$$

		Observed.		Limits.		No.	Calculated.	
		°	′	° ′	° ′		°	′
c p	001 : 111	48	18	47 59—	48 36	4	—	
c y	001 : $\bar{4}43$	56	3	55 55—	56 9	2	56	15
c a	001 : 100	89	41			1	90	0
c d	001 : $\bar{5}01$	70	17			1	68	47
c P	001 : 21.21.20	49	22½	49 17—	49 28	2	49	41
p p	111 : $1\bar{1}1$	83	7			1	—	
p y	111 : $\bar{4}43$	43	32			1	43	12
c x	001 : $\bar{7}01$	74	49			1	74	35

The correct interpretation of the measurements is to be found in the table on p. 212.

A remarkable feature about the mineral is that, whereas the Freiberg crystals show the face *P* and other forms which have simple indices when referred to *P* as (111), the Markirch crystals bear forms which can better be referred to *p* as (111).

One is at once led to imagine that the axial angle may really differ from 90°0′, and that *P* may be the primary pyramid in the positive, *p* in the negative octant. For the present, however, it is sufficient to establish the fact that the minerals from Freiberg and Markirch are identical, and that the axial ratios are nearly 2 : 1 : 1.

With the preceding measurements we may now compare those of Streng upon the mineral from Chañarcillo, which was described by him as fireblende, but being a compound of silver, sulphur and arsenic, is in reality xanthoconite.

The accompanying figure shows the form of the crystals measured by Streng, the orientation and lettering being changed so as to be uniform with those here adopted.

In Streng's description *c* is the plane of symmetry 010,

d is 110
r 919
P 515 and there are also faces of *t* 15.2.15
y 414
q 111
m 101

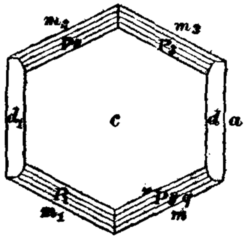


Fig. 3.

$cq = 81^\circ 0'$
$^*cP = 49^\circ 7'$
$^*cd = 69^\circ 40'$
$^*mm = 55^\circ 22\tfrac{1}{2}'$
$Pr = 42^\circ 2'$
$mm = 55^\circ 23'$

From the angles $c\,d$ and $m\,m$ the axes are calculated as

$$a : b : c = 0{\cdot}3706 : 1 : 0{\cdot}1944,\ \beta = 90^\circ 0'.$$

With the altered notation the axes will be $a : b : c = 1{\cdot}906 : 1 : 0{\cdot}972$, and both as regards form and habit the mineral is identical with xanthoconite.

(*c*). *Hardness.*—The hardness is, as stated by previous observers, between 2 and 3.

(*d*). *Colour.*—The superficial colour varies from brownish-yellow to vermilion-red, but by transmitted light thin crystals and fragments are always a clear lemon-yellow. The composition of the brown material analysed by Plattner indicates that the colour is probably affected by the presence of iron.

(*e*). *Streak.*—The streak is always a vivid orange-yellow.

(*f*). *Lustre.*—The lustre is adamantine; on the face *c* the lustre is inclined to pearly owing to the cleavage.

(*g*). *Optical Characters.*—Small tabular crystals of xanthoconite examined under the microscope through the face *c* show an extinction parallel to the edge *c d*; the double refraction is strong.

The crystals are biaxial with a very large angle; a negative bisectrix emerges nearly perpendicular to *c*, and the axial plane is parallel to the edge *c d*. By the use of the widest angled condenser and objective available the optic axes are brought within the field of view; dispersion marked, $\rho < v$.

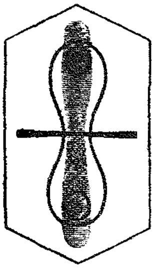


Fig. 4.

When the principal sections of the crystal coincide with those of the nicols, the dark cross of the interference figure is seen to be incomplete, the arm joining the optic axes being absent, while the perpendicular arm is well defined. This is easily explained if we suppose the xanthoconite crystal to consist of two overlapping plates united by the face *c*; the plane of symmetry of each is perpendicular to the edge *c d*, the axial plane of each is parallel to the edge *c d*; the bisectrix of each crystal is nearly coincident with the normal to *c*, but is slightly inclined thereto in the plane of symmetry, consequently the two plates are so united that their axial planes do not quite coincide although they both have the same plane of symmetry. These results are completely in accordance with the *geometrical* symmetry and twinning of the Markirch crystals; further confirmation is supplied by the appearance of the interference figure when a crystal was rotated about the longer diagonal of the rhomb by means of a stage goniometer constructed for the purpose, so that both optic axes could be brought successively into the field of view; it was then seen that the interference phenomena are due to the overlapping of two nearly coincident biaxial crystals.

With this goniometer it was also possible to measure approximately the axial angle in air; $2\ E = 125°$ about.

(*h*). *Chemical Characters.* [G. T. Prior.]—The material employed for analysis consisted of a number of small crystals collected from several Freiberg specimens. It was carefully picked out under the lens and microscope so as to free it from intermixed proustite, calcite and iron sulphides, and was finally treated with dilute acetic acid. Only about 25 milligrams were available for analysis. In consideration of the small weight of material it is necessary to give a somewhat detailed account of the methods employed.

The specific gravity determinations were made upon 0·0229 gram by means of a 3 cc. pyknometer, with the following results:—

(1). Weight of xanthoconite in air = 0·0229 gram.

Weight of xanthoconite with water filling the pyknometer at 16° = 3·0262 grams (mean of 6 determinations varying from 3·0259 to 3·0264).

Weight of water filling the pyknometer at 16° = 3·0075 gram; spec. grav. = 5·68.

(2). Weight of xanthoconite in air = 0·0227 gram.

Weight of xanthoconite with water filling the pyknometer at 16° = 3·0261 grams (mean of 9 determinations varying from 3·0258 to 3·0263).

Weight of water filling the pyknometer at 16° = 3·0076 grams (mean of 4 determinations varying from 3·0078 to 3·0074); spec. grav. = 5·40.

Mean of (1) and (2): spec. grav. = 5·54.

The method of analysis was the same as that employed in the case of pyrargyrite and proustite (*Min. Mag.* VIII. p. 94). The powdered mineral dried at 100° was transferred to a weighed porcelain boat and decomposed in a current of chlorine. The mineral was readily attacked, even in the cold; the colour changed quickly from orange (between 3 *p* and 4 *m* of Radde's scale) to bright yellow, but on warming it darkened again in parts to a deep red which gradually disappeared as the decomposition proceeded. The heating was by spirit lamp alone, and was continued until the silver chloride left in the boat just began to fuse. The silver chloride was weighed and then reduced in hydrogen ; the silver percentage deduced from the weight of silver obtained was practically identical with that resulting from the weight of chloride.

The purity of the metal was then tested by dissolving in nitric acid, &c.

The chlorides of sulphur and arsenic were absorbed in dilute HCl ; the sulphur, which at the commencement of the decomposition was seen to separate on the surface of the liquid in the receiver, was finally all converted into sulphuric acid. After driving off the chlorine and evaporating down at a very gentle heat the sulphur was precipitated by $BaCl_2$, and, after removal of the excess of the latter reagent, the arsenic was precipitated by H_2S. The sulphide of arsenic was washed with water, alcohol and carbon disulphide, dried and weighed. The sulphur in it was afterwards determined by oxidising with nitric acid and precipitating by $BaCl_2$. Both the filtrate and the $BaSO_4$ precipitate were tested for selenium by means of sulphur dioxide, but with negative results.

The analysis gave the following numbers :—

Weight of xanthoconite used	0·0253 gram.	
,, ,, AgCl ...	0·0219 gr.	Percentage of Ag = 65·15
,, ,, $BaSO_4$...	0·0351	,, ,, S = 19·07
,, ,, Sulphide of arsenic ...	0·0070	,, ,, As = 14·63
(Sulphur in this	0·0033)	
		98·85

The loss of one per cent. is in all probability chiefly due to the escape of traces of arsenic during the evaporations, and in the course of the processes connected with the two precipitations of $BaSO_4$.

In order to test the reliability of the above method as applied to such small weights of material, a preliminary analysis was made upon 0·0271 gram of proustite. The result as concerned the silver and sulphur was quite satisfactory ; the silver percentage obtained was 64·99, and that of the sulphur 19·98, the theoretical values being 65·40 and 19·43 ; the weight of sulphide of arsenic obtained was 0.0073 gram, which denotes a percentage of arsenic of 13·03 if the sulphide be regarded as As_2S_5 ; if, however, the sulphide be considered as a mixture of equal parts of As_2S_3 and As_2S_5 the number 14·72, which is nearer to 15·17, the theoretical value for proustite, is obtained. If the same supposition be made with regard to the arsenic sulphide precipitate in the case of the xanthoconite, the percentage of arsenic becomes 14·93.

The result of the analysis is therefore

$$\begin{aligned} Ag &= 65{\cdot}15 \\ S &= 19{\cdot}07 \\ As &= 14{\cdot}93 \\ \hline & \,99{\cdot}15 \end{aligned}$$

This analysis shows that xanthoconite has the same percentage composition as proustite; for, although much reliance cannot be placed in the number obtained for the arsenic, yet the results of the comparative analysis of the proustite in the case of the silver and sulphur, and a consideration of the method employed in their determination, inspires confidence as regards the numbers obtained for these constituents in spite of the small weight of material used. First, taking the case of the silver; the chloride is obtained as the residue left in the porcelain boat after decomposition of the mineral in chlorine, and is thus simply weighed in the same vessel in which the mineral was originally placed; accordingly no loss such as is incidental to processes of precipitation, filtration and ignition of precipitates is to be feared. The sulphur determination is not attended with the same advantages, since in this case such processes are necessary; but there is compensation in the fact that the precipitate weighs about ten times as much as the sulphur to be estimated, so that slight losses on that account do not very greatly affect the result.

The only analyses of xanthoconite hitherto published are those of Plattner, and these are open to some criticism.

In his first analysis made upon the brown variety it is true that as much as 0·5 gram seems to have been available, but the arsenic was not directly determined, and nearly one per cent. of iron was found, which is by Plattner himself referred to impurities. The silver percentage was 64·2, and therefore much nearer to 65·4, the theoretical value for proustite, than to 61·4, the percentage required by the sulpharsenate; the same moreover holds good for the sulphur, the percentage 21·36 being nearer to 19·4, the theoretical value for proustite, than to 24·3, that for the sulpharsenate.

If the iron be considered due to the presence of pyrites as impurity, Plattner's numbers become

$$Ag=65{\cdot}5 \quad S=20{\cdot}7.$$

The excess of sulphur may be due to the method of analysis, for no mention is made of the removal of the nitric acid after the fusion with nitre and sodium carbonate before the precipitation with $BaCl_2$.

In the account of the second analysis, made on the yellow variety, the weight used is not given; but that it was very small is evident from the fact that it was not sufficient to allow of the determination in the wet way, but only by the blowpipe. Breithaupt also speaks of the material as scarcely sufficient for the determination of the specific gravity.

Plattner himself recognised the fact that his numbers were closer to proustite than to the sulpharsenate by giving the somewhat improbable formula

$$(Ag_2S)_3\ As_2S_5+2\ (Ag_2S)_3\ As_2S_3.$$

This is the formula which generally appears in works on Mineralogy, but in the last edition of Dana's System its improbability seems to have been recognised, and the mineral is stated to be a sulpharsenate, having the formula

$$3Ag_2S\ .\ As_2S_5$$

although it would be more logical, if the old formula is to be rejected, to replace it by the formula of proustite.

Altogether it appears that the results of Plattner's analysis cannot be said to oppose the conclusions drawn from the present analysis—that xanthoconite has really the same empirical chemical composition as proustite.

IV. Description of Rittingerite.

(*a*.) *Modes of occurrence and association.*—The British Museum collection contains 10 specimens corresponding to both the two types described by Schabus and Schrauf. To the former belong those in which the rittingerite occurs in small rhombic tables of a dull yellowish colour associated with small scalenohedral crystals of proustite upon the decomposed surface of a quartzose veinstone rich in galena. If some of the loose material be shaken from these specimens and examined under the microscope, it is found to contain numerous minute crystals of rittingerite, proustite in slender prisms with scalenohedral terminations, quartz in doubly terminated prisms, and mica. These microscopic plates of rittingerite are honey-yellow and fairly transparent, and have fine linear faces upon their edges. Most of the crystallographic and optical determinations detailed below were made upon this material.

The rittingerite of the second type occurs in somewhat stouter rhombic tables dispersed singly, together with proustite, upon the pseudomorphous sulphide of iron known as "Silberkies;" these have a quartzose veinstone containing decomposing marcasite and are sometimes accompanied by pearlspar.

On one specimen which consists of nickeline and galena the rittingerite is dispersed, together with proustite, upon the nickeline.

The specimens of the first type are, as is stated by Zippe, from the Geistergang of the Eliaszeche.

On all these specimens the rittingerite appears to be contemporaneous with the proustite, and when these minerals occur upon silberkies they have very probably resulted from decomposition of argentopyrite or other silver mineral of which silberkies is an alteration.

(*b*). *Crystalline form.*—The rittingerite from Joachimsthal always occurs in small rhombic plates, with a plane angle of about 55°, having their edges bevelled by linear pyramid faces.

The larger crystals, and these include most of those which lie upon silberkies, are not suitable for accurate measurement, since they are composite crystals; the large face is curved and uneven, made up of segments belonging to different individuals, and the pyramid faces are composed of very minute striated planes.

Schabus, whose figure is here reproduced with an altered lettering, refers the mineral to the monosymmetric system, the plane of symmetry being parallel to the shorter diagonal and gives the following measurements:—

$cP = 49°10'$
$c'p = 47°36$
$cq = 98°30'$
$cr = 30°0'$
$Pp = 83°40'$

FIG. 5.

In modern notation the axial ratios which he calculates from these angles are—

$$a : b : c = 0{\cdot}506398 : 1 : 0{\cdot}508776$$
$$\beta = 88°26'$$

Calling the longer diagonal a, and the shorter diagonal unity, in order to bring the crystals into harmony with those described below, we have—

$$a : b : c = 1{\cdot}975 : 1 : 1{\cdot}005$$

The symbols of the faces are—

$P = 111$ $m = 110$
$r = 112$ $q = 66\bar{1}$
$Q = 661$ $p = 11\bar{1}$

Schabus further calculates the angles

$mm = 53°42'$ $pp = 140°1'$
$PP = 141°0'$ $Pp = 83°12'$
$Pp = 83°42'$

Schrauf proceeded in the following way: (1) the *plane* angle of the rhomb was determined by measurements on one crystal to be 55°40′; (2) the axial angle β was deduced from a second striated crystal which showed on the face c a line of junction (twin-union ?) parallel to the longer diagonal and a salient angle of 1°20′; *on the assumption* that this is due to twinning about the orthopinakoid,[1] the angle 100 : 001 is taken to be 89°20′, and the plane of symmetry is taken parallel to the shorter diagonal; (3) the angle 001 : $\bar{1}11$ was measured on a third crystal as 48°52′.

From these data the axial ratios are calculated as

$$a : b : c = 0{\cdot}52812 : 1 : 0{\cdot}52934$$
$$\beta = 89°20'$$

Making the shorter diagonal b ($=1$) in order to bring the crystals into harmony with those described below, we have

$$a : b : c = 1{\cdot}8935 : 1 : 1{\cdot}0024$$

The indices of the faces which yield reflections were found to be (115) (112) (334) (332) (16 . 16 . 3) (110) (0 . 16 . 3).

The very complete account which Schrauf gives of his measurements enables us to select with some confidence those readings which are most reliable, and to attach more weight to them than to the remainder.

It is important to do this, because his results do not accord very closely with those of Schabus nor with my own, and the discrepancies are no doubt to be ascribed to the imperfect nature of the crystals.

In the principal zone [$c\ m\ p$] it results from the combined observations of Schabus, Schrauf and myself, that there is a set of fairly well defined planes to which we may provisionally give the following letters and positions, corresponding to those used for xanthoconite :—

	Schabus.	Schrauf.	Inclination to *c*.
m	*M*	*m*	about 90°
q	*q*	*q*	„ 81°
ρ		*r*	„ 60°
P	*p′*	*π*	„ 49°
p	*p*	*p*	„ 48°
t			„ 36°
r	*r*	*o*	„ 30°
f		*f*	„ 13°

---

[1] This assumption is incorrect, since, as will be shown, the orthopinakoid is parallel not to the longer but to the shorter diagonal.

The only angles observed by Schrauf for which the readings are given to minutes are the following:—

Crystal 5.	$P q = 31°45'$
Crystal 6.	$c p = 47°15'$
	$c P = 48°25'$
	$c q_1 = 78°25'$
	$c q_2 = 79°25'$
	$c q = 79°$
	$c m = 87°45'$
	$c P = 129°35'$
Crystal 4.	$*c P = 48°52'$
	$c q_1 = 98°50'$
	$*c q_2 = 99°54'$
	$c P = 130°50'$
	$c r = 149°56'$
	$c P = 48°28'$
	$c q = 79°50'$
	$*c q = 98°48'$
	$c r = 150°35'$
	$p p = 83°15'$

(The value 99°48′ given for $c\,q$ on p. 231, must be a misprint.)

The best readings are distinguished by an asterisk.

The interpretation of these angles will be given subsequently; see the Table on p. 212.

My own measurements relate to seven crystals: numbers 1-5 are microscopic crystals belonging to the older variety; the last two were taken off silberkies, and belong to the second type.

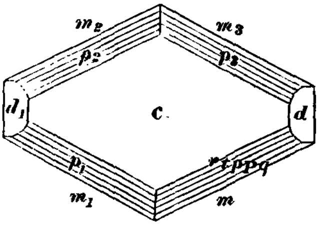


FIG. 6.

With each set of measurements are mentioned all the faces indicated by definite reflections, whether good or bad. The letters refer to fig. 6, which gives a general survey of the rittingerite crystals, and all the fragments measured are supposed to be orientated as in fig. 6. p' is parallel to p, p_1' to p_1 &c., as before.

Here, as in the case of xanthoconite, no account is taken of a vast number of indistinct and banded images obtained in the zone $c\,m$.

Crystal 1. Determinable faces, $c\ P\ q\ d\ p_3$

$cp_3 = 47^\circ 39'$ $p_3q = 108^\circ 7'$ $cP = 49^\circ 9'$

$cq = 79^\circ 43'$ $dq = 60^\circ 57'$

$*cd = 68^\circ 14'$ $p_3d = 56^\circ 17'$

Crystal 2. Determinable faces, $c\ r\ p\ r_3\ q_3\ c'\ r_1'$

$cp = 47^\circ 14'$ $cr_3 = 30^\circ 35'$

$cq_3 = 82^\circ 57'$ $c'r_1' = 30^\circ 50'$

Crystal 3. Determinable faces, $c\ m\ m_3\ P_3\ c'\ p'\ t'\ q_3'\ P_3'\ P_2'$

$cp = 47^\circ 27'$ $c'm = 87^\circ 38'$

$c'P_2' = 49^\circ 2'$ $c'P_3' = 48^\circ 38'$

Crystal 4. Determinable faces, $c\ r\ p\ m\ m_2\ p_1\ r_1\ q_2\ p_3\ c'\ r_1'\ p_1'\ P_3'\ q_3'\ \kappa$ (an orthodome).

$c'r_1' = 28^\circ 18'$ $cm = 94^\circ 45'$ $c\kappa = 28^\circ 37'$

Crystal 5. Determinable faces, $c\ P\ q\ d\ c'\ r_2'$

$c'd = 109^\circ 23'$ or $109^\circ 59'$ $c'r_2' = 30^\circ 9'$ $dP = 56^\circ 3'$

Crystal 6. Determinable faces, $c\ q\ P_3\ q_3\ c'\ r_1'\ q_1'\ r_2'\ q_2'$

$cq = 80^\circ 1'$ $cP_3 = 49^\circ 3'$ $qP_3 = 107^\circ 54'$ $qq_3 = 120^\circ 54'$ or $121^\circ 42'$

Crystal 7. Determinable faces, $c\ r\ P\ q\ d\ P_3\ q_3\ m_3\ P_1'\ d'\ r_2'\ P_2'$

$c'd' = 68^\circ 54'$ $*d'q_3 = 68^\circ 9'$ $cP_1' = 129^\circ 38'$ or $130^\circ 17'$

$c'r_2' = 31^\circ 32'$ $d'P_2' = 55^\circ 45'$ $c'P_2' = 48^\circ 21'$ or $49^\circ 52'$

$cq_3 = 79^\circ 22'$ $d'r_2' = 57^\circ 49'$

The best angles are afforded by crystal 1. The faces $q\ d\ p_3$ are very perfect, and even c yields a single and well defined image. From the three angles cp_3, p_3d, dc, that between the zones cp_3 and cd is calculated to be 63°36′; from the three angles cq, qd, cd, that between the zones cq and cd is calculated to be 62°41′. The sum of these is 126°17′ and should be the plane angle of the face c; now from the three measurements cp_3, cq, p_3q the same angle is calculated as 126°22′. The measurements on this crystal can therefore be relied on as concordant and accurate.

There are three ways in which they may be interpreted, and similar considerations may be applied to each of the remaining six crystals.

(1). The crystal is orthorhombic, and the want of symmetry is merely due to different pyramids being developed upon the different edges.

(2). The crystal is monosymmetric, it being still doubtful whether the plane of symmetry is parallel to the shorter or the longer diagonal of the rhomb.

(3). The crystal is anorthic, since the angle between the zones cp_3 and cd is not absolutely identical with that between cq and cd, as it should be in the monosymmetric system.

In the first place the angles themselves are very nearly in accordance with the requirements of the orthorhombic system.

Thus in the accompanying stereographic projection on a plane which contains the shorter diagonal of the rhomb and the normal to c, the angle $c\ d\ q$ as calculated from cd, cq and dq is $90°6'34''$, and therefore $bc = 89°52'52''$

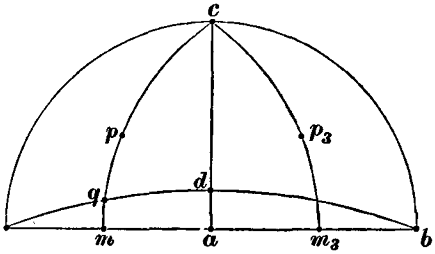


FIG. 7.

Hence taking a as 100
b 010
c 001
p 111

and calculating from $cp = 47°39'$
$bm = 63°9'$

the crystal may be referred to three rectangular axes

$$a : b : c = 0{\cdot}50642 \ ; \ 1 : 0{\cdot}49563$$

or making a the longer and b the shorter diagonal

$$a : b : c = 1{\cdot}97465 : 1 : 0{\cdot}97869,$$

and we get $q = 551$ $cq = 79°40'$ (calculated) $79°43'$ (observed)
$d = 501$ $cd = 68°2'$ „ $68°14'$ „

But in this case P either belongs to the form $\{111\}$, and cP should be $47°39'$ instead of $49°9'$ as observed, or else P has indices approximating to (21.21.20).

It is true that in this crystal the angle $c\ P$ is precisely the one which is most doubtful, but on the other hand the best angular measurement on crystal 2 gives $49°2'$, and one of Schabus' angles is $49°10'$.

Further a microscopic examination of this crystal shows that c is nearly perpendicular to a bisectrix, the plane of the optic axes being parallel to the shorter diagonal of the rhomb. Extinction is parallel to the diagonals, but the bisectrix emerges with a slight inclination (one or two degrees at most) to the normal of *c*, the divergence being in the longer diagonal of the rhomb.

These considerations negative the orthorhombic and anorthic systems, and justify us in ignoring the slight difference of 0°55′ between the angles *p c d* and *q c d*, especially when the individual variations in the remaining crystals are borne in mind; hence we may conclude that the crystal belongs to the monosymmetric system, the plane of symmetry being parallel to the longer diagonal, and not to the shorter diagonal, as supposed by Schabus and Schrauf.

Then, calculating from the data

$$c\,p = 47°39'$$
$$c\,q = 79°43'$$
$$a\,c\,p = 63°9' = a\,c\,q$$

and assuming $p = (111)$ and $q = (551)$,

we obtain for this crystal (No. 1) $100 : 001 = 90°8'20''$.

Hence within the limits attainable by the measurements the axes may be regarded as rectangular, and the elements and axes deduced from this particular crystal are $a : b : c = 1{\cdot}97555 : 1 : 0{\cdot}97879$, $\beta = 90°$; then the indices of the faces given in the table on p. 202 are as follows :—

$c = 001$
$m = 110$
$p = 111$
$P = 21.21.20$
$d = 501$
$q = 551$
$\rho = 332$
$t = 223$
$r = 112$
$f = 115$

We have hitherto confined our attention to crystal 1, because the three cross-measurements which it affords are extremely good and are concordant, and because they prove that rittingerite may be referred, at any rate as a first approximation, to three rectangular axes.

The next step is to combine the measurements from all the six crystals described above, as well as those of Schrauf and Schabus, and as basis of calculation are taken the angle *q d* as measured on crystal 1, and the angle *c q* as deduced from crystals 1, 2, 6, 7,

$a : b : c = 1{\cdot}928 : 1 : 0{\cdot}995\ ,\ \beta = 90°.$

		Observed.		Limits.				No.	Calculated.	
		°	′	°	′	°	′		°	′
c κ	001 : 105	28	37					1	27	32
c d	001 : 501	69	26	68	14—	70	37	4	69	0½
c r	001 : 112	30	16	28	18—	31	32	5	29	31
c p	001 : 111	47	27	47	14—	47	39	3	48	33
c P	001 : 21.21.20	49	16	48	21—	50	22	8	49	56
c q	001 : 551	79	59	79	22—	80	13	4	—	
c	001 : 771	82	57					1	82	48½
c m	001 : 110	86	26	85	15 –	87	38	2	90	0
p d	111 : 501	56	17					1	55	59½
p q	111 : 5$\bar{5}$1	108	7					1	107	45
d q	501 : 551	60	57					1	—	
d q	50$\bar{1}$: 551	68	9					1	68	50½
d P	501 : 21.21.20	55	52	55	45—	56	3	2	55	59
q P	551 : 21.$\overline{21}$.20	107	54					1	108	57
q q	551 : 5$\bar{5}$1	120	18	120	54—	121	42	2	124	38

To compare with the above, we have from Schabus

		Observed.	
		°	′
c P	001 : 21.21.20	49	10
c p	001 : 111	47	36
c q	00$\bar{1}$: 551	98	30
c r	001 : 112	30	0
P p	21.21.20 : 111	83	40

From the reliable measurements of Schrauf the following:—

		Observed.		Limits.				No.
		°	′	°	′	°	′	
c r	00$\bar{1}$: 112	150	15	149	56——	150	35	2
c p	001 : 111	47	15					1
c P	001 : 21.21.20	49	4	48	25——	50	25	5
c q	001 : 551	79	53	79	0——	81	10	7
c m	001 : 110	87	45					1
p p	111 : 1$\bar{1}$1	83	15					1
p q	111 : 551	31	45					1

The correct interpretation of these measurements is to be found in the table of calculated angles on p. 212.

I have here ventured to take the measurements of Schrauf, and to give them a different interpretation from his. The table is simply constructed from the observations on the three crystals quoted on p. 203.

A sufficient justification is to be found in the very complete and intelligible record of measurements published by Schrauf. Here, as in the case of all imperfect crystals, it is of more importance to have the actual readings than the means deduced from them, and for this reason a similar course has been pursued in the present paper in the descriptions of both xanthoconite and rittingerite, in the hope that they may be corrected and perfected by subsequent observers.

An attempt has here been made to determine the form of the rittingerite from Joachimsthal, independently of any reference to xanthoconite. The nature of the material renders it impossible to do this with accuracy; for instance, the discrepancy between the observed and calculated values of *c p* indicates that the determination is only approximate. It is, however, possible to assert positively that the crystals are rhombs, having a plane angle of about 54°, and belonging to the monosymmetric system; referable to three nearly rectangular axes having nearly the ratios $2:1:1$; and that the dome face *d* upon the acute angle of the rhomb is inclined at an angle of about 69½° to the basal plane.

It is impossible from the measurements *alone* to say with certainty whether the plane of symmetry is parallel to the shorter or longer diagonal of the rhomb; but the evidence is in favour of the latter.

The crystals are almost always composite, consisting of several individuals twinned upon *c*; from this cause the face *c* is very rarely smooth.

Cleavage is distinct, parallel to *c*.

(*c*.) *Hardness*.—The hardness is, as stated by Zippe, between 2 and 3.

(*d*.) *Colour*.—The superficial colour of the crystals belonging to the older occurrence is a dull orange yellow inclined to red; that of the more recent occurrence is a more lustrous orange red, even somewhat resembling proustite on a fractured surface.

By transmitted light thin plates or fragments are always of a clear lemon yellow.

(*e*.) *Streak*.—The streak is always a vivid orange yellow.

(*f*.) *Lustre*.—The lustre is adamantine; sometimes inclined to pearly on the face *c*.

(*g*.) *Optical Characters*.—As regards magnitude and sign of double refraction, position of the optic axes, dispersion and twinning, thin crystals of rittingerite are identical with xanthoconite.

The axial plane is parallel to the shorter diagonal of the rhombs; a negative bisectrix emerges nearly normal to *c*, but slightly inclined in the plane of the longer diagonal; birefringence rather strong; $2E = 120°$ about; $\rho < v$.

All the crystals are composed of overlapping plates twinned on *c*, which give rise to the same interference figure as that described on p. 196; in fact, all that is said there is applicable to rittingerite.

(*h.*) *Chemical Characters.* [G. T. Prior.]—A complete analysis was impossible owing to lack of material; only about 4 milligrams were available.

The result of the specific gravity determination was as follows:—

(*α.*) Weight of rittingerite in air = 0·0046 gram.

(*β.*) Weight of rittingerite with water in the pyknometer when filled up to the index mark:—

3·0115	grams at	14°·6	*i.e.*	3·0109	grams at	16°
3·0114	,,	14°·8		3·0109	,,	,,
3·0109	,,	15°·8		3·0108	,,	,,
3·0110	,,	15°·5		3·0110	,,	,,
3·0110	,,	15°·8		3·0109	,,	,,
3·0114	,,	15°·2		3·0110	,,	,,
3·0109	,,	15°·8		3·0108	,,	,,
3·0108	,,	16°		3·0108	,,	,,
		Mean =		3·01089	grams at	16°

(*γ.*) Weight of water alone in the pyknometer when filled up to the index mark—

	3·0072	grams at	16°
	3·0072	,,	,,
	3·0071	,,	,,
	3·0072	,,	,,
Mean	3·00717		

Hence specific gravity = 5·2.

This result is the mean value to be deduced from the weighings; but since a difference of $\frac{1}{10}$ milligram in any of the weighings corresponds to a difference of about ·5 in the specific gravity, all that can be said in dealing with so small a weight of material is that the specific gravity lies between 5 and 6.

In the analysis, all that could be attempted was the determination of the silver. For the reasons stated on p. 129, some reliance can be placed on this determination, even with such a small weight of material. The mineral was decomposed in a current of chlorine as in the case of xanthoconite; similar changes of colour were noted during the decomposition, and traces of sulphur were seen to separate on the surface of the dilute hydrochloric acid in the receiver.

The weight of rittingerite taken was 0·00380 gram, and the weight of silver chloride obtained was 0·00319 gram, which corresponds to 63·2 per cent. of silver; the weight of silver obtained on reduction was 0·00243 gram, which gives 64·00 per cent.

Within the limits attainable this is practically identical with the result for Xanthoconite.

As regards the other constituents absorbed in the dilute hydrogen chloride in the receiver, the presence of sulphur was clearly demonstrated by precipitation with barium chloride. This precipitate and the filtrate were carefully tested for selenium by means of sulphur dioxide, but with negative results. The arsenic was precipitated by H_2S; the precipitate was somewhat dark-coloured, but no antimony could be detected by the barium tartrate microchemical test in the slight residue obtained on treating with hot strong hydrochloric acid and evaporating down. On the other hand the presence of arsenic was confirmed by oxidising with nitric acid and precipitating with magnesia mixture.

Portions of the matrix from two specimens of rittingerite were tested for selenium, but with negative results.

In opposition to the above we have the investigation of Schrauf, who found that rittingerite contains silver, arsenic, and *selenium*, with a silver percentage of 57·7.

We must contend, however, that the method which we have employed for the determination of the silver is more reliable than the method (reduction on charcoal) made use of by Schrauf, and point out that the only proof which he gives of the presence of selenium is the smell which he noticed on heating the mineral.

On the other hand, in confirmation of the absence of selenium, we have the micro-chemical observations of Streng.

V. THE IDENTITY OF XANTHOCONITE AND RITTINGERITE.

In the preceding sections it has been necessary, in order to make the proof complete, to keep the observations on the two minerals perfectly distinct. In the absence of complete analyses each has been treated as a separate mineral, and the calculations have been made independently.

Brought into the same position, and referred to the same parametral plane, the different crystals which have been measured have received the following axial ratios :—

Xanthoconite	(Freiberg)	1·921 : 1 : 1·034	$\beta = 90°$	Miers
,,	(Markirch)	1·936 : 1 : 1·003	$\beta = 90°$	,,
,,	(Chañarcillo)	1·906 : 1 : 0·972	$\beta = 90°$	Streng
Rittingerite		1·8935 : 1 : 1·002	$\beta = 89°20'$	Schrauf
,,		1·975 : 1 : 1·005	$\beta = 88°26'$	Schabus

Rittingerite (Crystal 1) 1·975 : 1 : 0·979 $\beta = 90°0'$ Miers
„ 1·928 : 1 : 0·995 $\beta = 90°0'$ „

The angle β of Schrauf and Schabus is that of the axes *b c*.

These numbers in themselves suggest forcibly that they all relate to one and the same mineral.

The preceding pages have completed the evidence by establishing those characters which were left doubtful by previous observers, namely, the form of xanthoconite and the composition of rittingerite, and have proved conclusively that the two substances are identical in composition and physical characters, as well as crystalline form.

The independent calculations have now therefore become superfluous; the axial ratios given above are only first approximations, and we may now fix the crystalline form of the mineral xanthoconite by combining the measurements of both varieties, recollecting that the crystals are almost invariably twinned.

The chief difficulties to be decided are (1) whether the angle β differs appreciably from 90°; (2) which of the forms belong to positive and which to negative hemi-pyramids; (3) which of the angles obtained for 001 : 111 (*c p*) is correct.

The following are the very best individual angles measured :—

Xanthoconite *cm* = 90°8′
am = 62°28′
mm = 55°5′ (mean of 55°3′ and 55°7′)
dq = 61°2′
cp = 48°23′ (mean of 48°10′ and 48°36′)
pp = 83°7′
cy = 56°9′
Rittingerite *cd* = 68°14′
d′q = 68°9′

In the first place, it may be regarded as certain that 62°28′ is the true angle for *a m*, since it agrees exactly with the angle measured for *m m*.

Next, taking *a m* = 62°28′ and *d q* = 61°2′, and assuming that the zone *d q* is perpendicular to the zone *c d* in accordance with the requirements of the monosymmetric system, and as proved to be the case on crystal 1, we calculate *c d* as approximately 70°21′, which does not agree with the measured angle 68°14′; it does, however, agree with the angle determined on the Markirch xanthoconite, and this suggests that the one angle *c d* = 68°14′ may belong to the negative, and the other *c D* = 70°21′ to the positive orthodome (101).

From these values 001 : 501 = 68°14′
001 : $\bar{5}01$ = 70°21′

we calculate *ac* = 100 : 001 = 88°47½′
cm = 001 : 110 = 89°26′

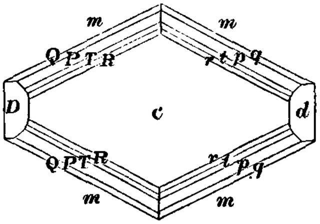


Fig. 8.

The angle *a c* is nearly identical with *c a* measured on the Markirch mineral, and *c m* is comparable with the angle 89°52′ obtained from Freiberg xanthoconite.

Without, therefore, pretending to any great degree of accuracy, we may refer the mineral to the following elements :—

$$a : b : c = 1{\cdot}9187 : 1 : 1{\cdot}0152$$
$$\beta = 88°47'$$

with the angles

ac	100 : 001	88°47′	*cY*	001 : $\bar{4}43$	57°19′
	001 : 101	27°37′	*cq*	001 : 551	79°32′
	001 : $\bar{1}01$	28°9′	*cQ*	001 : $\bar{5}51$	80°38′
cd	001 : 501	68°14′	*pp*	111 : $1\bar{1}1$	83°18′
cD	001 : $\bar{5}01$	70°21′	*PP*	$\bar{1}11$: $\bar{1}\bar{1}1$	84°18′
cn	001 : 053	59°24′	*qq*	551 : $5\bar{5}1$	121°21′
cm	001 : 110	89°26′	*QQ*	$\bar{5}51$: $\bar{5}\bar{5}1$	122°6′
am	100 : 110	62°28′	*pd*	111 : 501	55°27′
mm	110 : $\bar{1}10$	55°4′	*PD*	$\bar{1}11$: $\bar{5}01$	56°41′
cr	001 : 112	29°38′	*dq*	501 : 551	60°40′
cR	001 : $\bar{1}12$	30°12′	*DQ*	$\bar{5}01$: $\bar{5}51$	61°3′
ct	001 : 223	37°8′	*dD*	501 : $50\bar{1}$	41°24′
cT	001 : $\bar{2}23$	37°48′	*pD*	111 : $50\bar{1}$	84°3′
	001 : 334	40°24′	*Pd*	$\bar{1}11$: $\bar{5}0\bar{1}$	85°16′
	001 : $\bar{3}34$	41°7′	*Dq*	$50\bar{1}$: 551	68°27′
cp	001 : 111	48°32′	*pq*	111 : 551	31°0′
cP	001 : $\bar{1}11$	49°10′	*PQ*	$\bar{1}11$: $\bar{5}51$	31°27′
cy	001 : 443	56°22′			

If these angles be compared with the measurements given in the tables above, it will be found that they agree more closely with the best readings than do the angles previously calculated on the assumption that $\beta = 90°$.

As regards the angle *c p* or *c P*, three values have been found, namely:—

$c\pi = 47°27'$ on rittingerite
$cp = 48°18'$ on xanthoconite
$cP = 49°22'$ on both.

According to the above interpretation, the two latter are the positive and negative hemi-pyramids. It is impossible to ignore the face π, because it also occurs in the measurements of Schrauf and Schabus. It is, of course, conceivable that the mineral may be in reality anorthic, but in the present state of our knowledge it is better to regard this plane as a face vicinal to *p* or *P*. The crystals described above indicate that it occurs in the positive octants, and is therefore vicinal to *P*.

We have then, finally, for the characters of xanthoconite

System monosymmetric
$a : b : c = 1{\cdot}9187 : 1{\cdot}10152 \quad \beta = 88°47'$
common forms

p	111	*P*	$\bar{1}11$
q	551	*Q*	$\bar{5}51$
d	501	*D*	$\bar{5}01$
m	110	*c*	001

usual habit, fig. 1; from Joachimsthal (rittingerite) fig. 6; from Markirch, fig. 2.

Twin-plane *c*, common. Cleavage distinct, *c*; fracture, subconchoidal; brittle; hardness between 2 and 3; sp. g. = 5·54; lustre, adamantine to pearly; superficial colour, brown, orange or red; colour by transmitted light, lemon yellow; streak, orange yellow; optic axial plane perpendicular to the plane of symmetry; birefringence strong, negative; 2 *E* about 125°; $\rho < v$; acute bisectrix nearly normal to *c*.

Composition; Ag_3AsS_3 or $3Ag_2S{\cdot}As_2S_3$
$Ag = 65{\cdot}4,\ As = 15{\cdot}2,\ S = 19{\cdot}4.$

VI. THE FAMILY OF THE RED SILVERS.

In the group of the red silvers are to be included the sulph-arsenites and sulph-antimonites of silver which have received the names of proustite, pyrargyrite, xanthoconite, rittingerite, sanguinite and fireblende.

Rittingerite and xanthoconite are now to be united under the latter name, rittingerite being only a synonym for the Joachimsthal occurrence.

Fireblende, according to the analysis of Hampe, has the composition of pyrargyrite (*Zeits. f. Krystallographie*, vi. (1882) 572); we should therefore expect it to be isomorphous with xanthoconite, considering the well established isomorphism of pyrargyrite and proustite.

According to the measurements of Luedecke, fireblende belongs to the monosymmetric system

$$a : b : c = 0{\cdot}3547 : 1 : 0{\cdot}1782 \qquad \beta = 90°0'$$

Now the mineral crystallises in thin plates with a habit which instantly reminds one of that of xanthoconite. It has a prism angle (53°21′) near that of xanthoconite (55°5′); and it shows the same tendency to parallel or nearly parallel grouping. The crystals consist of bundles or sheaves of thin plates, and are almost invariably overlapping twins, as is remarked by Luedecke.

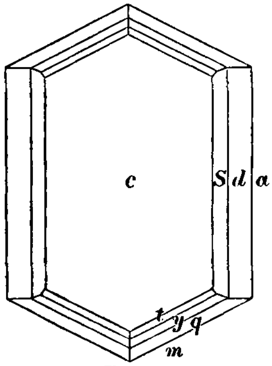


Fig. 9.

The accompanying figure shows the form of fireblende as determined by Luedecke, but the orientation and lettering of the crystal are altered so as to bring them into harmony with those adopted for xanthoconite.

According to Luedecke and previous observers (Miller and Roemer) the plane of the plate is the plane of symmetry; but the crystals are nearly orthorhombic in form, and Luedecke's measurements show that they may, like xanthoconite, be referred to three rectangular axes.

With the new position and parametral plane, the axial system is

$$a : c : b = 1{\cdot}9465 : 1 : 1{\cdot}0973 \qquad \beta = 90°0'$$

c = 010 (b)
m = 101 (d)
a = 001
t = 232 (o)
y = 434 (p)
q = 515 (π)
S = 520 (S)
d = 510 (m)

The letters in brackets are those used by Luedecke. The letters used here are chosen to indicate the probable identification of the faces observed by Miller and Luedecke, the calculated angles being

mm = 53°21′
ct = 34°54′
cy = 57°30′
cq = 72°20′
cS = 54°39′
cd = 70°28′

The measurements of Luedecke are by no means concordant, neither do they agree with those of Miller, so that the form of fireblende cannot be regarded as determined with certainty.

The face *c* is regarded as the plane of symmetry on account of the optical characters. Luedecke found that the direction of extinction is not straight, but makes an angle of 8°—11° with the edge *c d*. That the direction of extinction cannot be straight is proved by the fact that the twin crystals do not become dark in any position between crossed nicols.

This indicates that the symmetry is certainly different from that of xanthoconite; but the geometrical similarity of the two substances is so great that they must necessarily be considered as isomorphous.

We have, then, in these two minerals, a very interesting example of isomorphism in the same system with different orientation. They crystallise in rhombic-shaped plates, having an angle of about 54°, and belonging to the monosymmetric system: but whereas in xanthoconite the plane of symmetry is perpendicular to the plate and parallel to its longer diagonal, in fireblende it is parallel to the plane of the plate.

The present paper brings to a close the researches which I have made, with the help of Mr. Prior, during a course of several years, into the nature of the red silver ores.

We may now gather up the information which we possess regarding this interesting group of minerals, and classify the red silvers as follows:—

	Rhombohedral.	Monosymmetric.	
Ag_3SbS_3	Pyrargyrite	Fireblende	
	$a : c = 1 : 0\cdot7892$	$a : c : b = 1\cdot9465 : 1 : 1\cdot0973$	$\beta = 90°0'$
	$G = 5\cdot85$	$G = 4\cdot3$ (?)	
Ag_3AsS_3	Proustite	Xanthoconite	
	$a : c = 1 : 0\cdot8038$	$a : b : c = 1\cdot9187 : 1 : 1\cdot0152$	$\beta = 88°47'$
	$G = 5\cdot57$	$G = 5\cdot54$	

Sulpharsenite of silver—sanguinite—probably rhombohedral.

It is evident that a more complete and accurate determination of fireblende is needed. The specific gravity is probably greater than 4·3, the number given by Miller. The material in the British Museum is not, however, suitable for accurate measurements, and I am obliged to content myself with the observations of Luedecke, merely adding to his description the fact that the mineral has strong positive birefringence.

It results from the preceding comparison that the analogy between the red silvers and the calcite-aragonite groups is not so close as is often stated. The second modifications of pyrargyrite and proustite are not orthorhombic as was supposed to be indicated by bournonite, but are monosymmetric and present no similarity to aragonite. There is no reason to regard the red silvers as in any sense isodimorphous with the carbonates, and we are not justified in supposing that the similarity of angle in the rhombohedral modifications is due to a similarity of composition,

NOTE.—The general results of the present paper were stated in *Nature*, Vol. 47, p. 70.