Sulpharsenites of Lead from the Binnenthal.[1]

PART II.—*Rathite.*

By R. H. SOLLY, M.A.

(With Plate III.)

[Read November 13th, 1900.]

RATHITE, $3PbS.2As_2S_3$.

Literature.

Baumhauer, 1896, Zeits. Kryst. Min. XXVI, 593-602. Crystallography. with Analysis by Bömer. (Abstract Min. Mag. XI, 225.)

Jackson, 1900, Min. Mag. XII, 287. Analyses.

Crystallography.

System: Rhombic. $a:b:c=0{\cdot}4782:1:0{\cdot}5112$.

These ratios are calculated from $010:350=51°27'$ and $010:111=70°45'$ measured on crystal No. 1 (see p. 81). A new orientation has been chosen for the crystals, so that the well-developed prism zone is vertical, and the cleavage plane, (001) of Baumhauer, becomes (010) to correspond with the cleavage of jordanite. The parametral plane has also been changed, chiefly on account of the pyramid planes. The corresponding forms being:—

Baumhauer	100	010	001	403	095	20.27.0	20.27.15
Solly	100	001	010	110	011	101	111

The axial ratios $a:b:c=0{\cdot}668099:1:1{\cdot}057891$, as given by Baumhauer, become on recalculation $a:b:c=0{\cdot}4737:1:0{\cdot}5251$.

The crystallographic observations have been made on 25 crystals, obtained from the Lengenbach quarries, in the Binnenthal. The table on page 78 contains a list of 62 known forms, 37 of which have not been observed before.

The base (001) is very rare, and only present as a very narrow plane. The brachypinacoid (010) is always present. The macropinacoid (100)

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[1] Part I, General Description and Chemical Analyses, with a Crystallographic Account of Jordanite. Min. Mag. 1900, XII, 282-297.

is rare, though sometimes fairly well developed. The crystals are always elongated along the Z axis. In the prism-zone (320), (340), (120) and (380) are characteristically well developed planes. The brachydome (011) is often largely developed and finely striated parallel to the X axis. The macrodome (101) is sometimes largely developed and deeply furrowed parallel to its intersection with (111). The pyramid planes, though numerous on some crystals, are always small and brilliant.

LIST OF KNOWN FORMS.

Symbol.	Indices.	Baumhauer's Indices.	Symbol.	Indices.	Baumhauer's Indices.	Symbol.	Indices.	Baumhauer's Indices.
a	100	..	$\frac{5}{2}r$	250	..	$\frac{8}{3}k$	083	..
b	010	001	$\frac{7}{3}r$	370	..	$\frac{7}{3}k$	073	045
c	001	..	$\frac{9}{4}r$	490	7.0.12	$\frac{9}{5}k$	095	..
h	101	..	$2r$	120	203	†$\frac{7}{4}k$	074	..
$\frac{80}{3}r$	3.80.0	..	$\frac{7}{4}r$	470	..	$\frac{5}{3}k$	053	0.11.10
$18r$	1.18.0	..	$\frac{5}{3}r$	350	405	$\frac{4}{3}k$	043	..
$11r$	1.11.0	..	$\frac{4}{3}r$	340	101	k	011	..
$10r$	1.10.0	..	r	110	403	$\frac{10}{11}k$	0.10.11	021
$9r$	190	107	$\frac{8}{7}s$	870	302	$\frac{5}{6}k$	056	..
$8r$	180	106	$\frac{3}{2}s$	320	201	$\frac{1}{3}k$	013	0.16.3
$\frac{22}{3}r$	3.22.0	2.0.11	$2s$	210	..	$\frac{11}{3}q$	3.11.3	..
$7r$	170	..	$3s$	310	401	$3q$	131	..
$\frac{20}{3}r$	3.20.0	105	$4s$	410	..	$\frac{5}{2}q$	252	..
$6r$	160	209	$\frac{9}{2}s$	920	601	$\frac{7}{3}q$	373	..
$\frac{17}{3}r$	3.17.0	8.0.35	$7s$	710	..	$\frac{5}{3}q$	353	..
$\frac{16}{3}r$	3.16.0	..	$8s$	810	..	p	111	..
$\frac{14}{3}r$	3.14.0	207	†$15k$	0.15.1	..	$3t$	313	..
$4r$	140	103	$7k$	071	..	$5t$	515	
$\frac{11}{3}r$	3.11.0	23.0.66	$5k$	051		$2p$	211	..
$\frac{10}{3}r$	3.10.0	205	$\frac{7}{2}k$	072	..	$2m$	122	..
$3r$	130	..	$3k$	031	..	$\frac{3}{2}w$	132	..
$\frac{8}{3}r$	380	102						

† Twin planes, not found as faces.

The colour is lead-grey, but sometimes steel-grey, due probably to the inclusion of minute crystals of iron pyrites. Sometimes beautifully tarnished like jordanite. Streak chocolate colour. Opaque. Very perfect cleavage parallel to (010)[1]; also a parting parallel to (100). Fracture conchoidal. Hardness 3. Specific gravity 5·412, also 5·421: Baumhauer found 5·32. It is sometimes intimately associated with sartorite. The only known locality is the bed of the Lengenbach, Binnenthal.

[1] See Min. Mag. Vol. XII, 286.

Five different *habits* have been observed :—

I. Small, very brilliant lead-grey crystals, highly modified, showing little or no twinning. Fig. 1, Plate III.

II. Stout crystals of typical rhombic habit; (010) (011) (101) and prism faces are largely developed. Colour lead-grey to steel-grey. The most characteristic features of this habit are the numerous twin lamellæ and the parting parallel to (100). Analysed by Jackson (*loc. cit.* No. 13). This habit resembles Baumhauer's crystals, I and VI? Figs. 2 and 3.

TABLE OF CALCULATED ANGLES.

Zone [010, 100].	010, 870 = 67°17½′	Zone [010, 101].
010, 3.80.0 = 4°29′	, 320 = 72 19	010, 3.11.3 = 37°59½′
, 1.18.0 = 6 37½	, 210 = 76 33	, 131 = 43 40
, 1.11.0 = 10 46	, 310 = 80 56½	, 252 = 48 53
, 1.10.0 = 11 49	, 410 = 83 11	, 373 = 50 49½
, 190 = 13 5	, 920 = 83 56	, 353 = 59 48
, 180 = 14 39	, 710 = 86 5½	, 111 = 70 45
, 3.22.0 = 15 55	, 810 = 86 35	, 313 = 83 21½
, 170 = 16 38	, 100 = 90 0	, 515 = 86 0
, 3.20.0 = 17 25	Zone [010 : 001].	, 101 = 90 0
, 160 = 19 13	010, 0.15.1 = 7 26	Zone [010, 102].
, 3.17.0 = 20 15½	, 071 = 15 37	010, 132 = 55 56
, 3.16.0 = 21 24½	, 051 = 21 22	, 122 = 65 44
, 3.14.0 = 24 8½	, 072 = 29 12	Zone [100, 011].
, 140 = 27 36	, 031 = 33 6½	100, 211 = 27 43
, 3.11.0 = 29 42	, 083 = 36 16	, 111 = 46 25
, 3.10.0 = 32 6	, 073 = 39 59	, 122 = 64 33
, 130 = 34 52½	, 095 = 47 23	, 011 = 90 0
, 380 = 38 6½	, 074 = 48 11	.. ..
, 250 = 39 54½	, 053 = 49 34	010, 211 = 77 47
, 370 = 41 52	, 043 = 56 20½	100, 101 = 43 5½
, 490 = 42 54	, 011 = 62 55½	001, 211 = 65 32
, 120 = 46 16½	, 0.10.11 = 65 4½	, 111 = 49 50
, 470 = 50 4½	, 056 = 66 55½	, 353 = 53 48½
, 350 = 51 27	, 013 = 80 20	, 122 = 36 29
, 340 = 57 29	, 001 = 90 0	, 373 = 58 1½
, 110 = 64 26½		, 252 = 59 1½
		, 132 = 43 4
		, 131 = 61 51
		, 3.11.3 = 65 8

III. Flat rhombic prisms, with narrow (010) and well developed brachydomes. Exhibiting twin lamellæ, but not so numerous or so well marked as in habit II. Analysed by Jackson (No. 11). Fig. 4.

IV. Large rough crystals with splendid (010) cleavage; *no twin lamellæ*; of a dark steel-grey colour; usually mistaken for dufrenoysite. Similar to crystals II and III of Baumhauer. Analysed by Jackson (No. 12).

V. Rounded prisms roughly terminated, with very numerous fine twin lamellæ; of a lead-grey colour sometimes beautifully tarnished. Similar to crystal IV of Baumhauer. Fig. 5.

Twin laws.

I. Twin plane (074).

This twinning is only indicated by numerous very fine twin lamellæ.

II. Twin plane (0.15.1).

This is rare as a juxtaposed twin (Fig. 3), but fairly common as shown by small blade shaped prisms grown on the prism of the principal crystal. Two twinned crystals, as shown in Fig. 2 and in Baumhauer's Fig. 2, have been observed forming a triplet. The planes (074) (0.15.1) are not developed on any of the crystals.

Baumhauer, in his description of rathite, discusses the following possible causes of the fine striæ.

(*a*) Are the layers due only to parallel growth?

(*b*) Are the layers due to twin growth?

(*c*) Are the layers due to alternate banding of two isomorphous substances?

On account of the analysis obtained by Bömer, Baumhauer considered that the fine striæ are due to alternate banding of $PbAsS_3$ and $PbSbS_3$ in the proportion of five molecules of the former to one of the latter. Jackson, out of five analyses of different rathite crystals, only once found any antimony (0·43 per cent.), while Bömer made one analysis and found 4.53 per cent. of antimony. I think there can be no doubt that the true composition of rathite is expressed by the formula $3PbS.2As_2S_3$, and therefore the chemical composition has nothing to do with the fine striæ.

Are the layers then parallel growths or twin growths? Parallel layers would require some impurity between each layer, but Jackson did not find any difference in the chemical composition between crystals showing the lamellar structure and those not showing it. Parallel layers, as a rule, are uneven in thickness, and pass through the whole crystal. Now, these layers are remarkable for their even thickness, and do not always spread through the whole crystal or exhibit a pseudo-cleavage parallel to the layers. In the juxtaposed twin, described on page 83, one crystal shows lamellar structure, while in the other it is absent.

I therefore consider that the fine striæ are caused by twin lamellæ parallel to (074).

Baumhauer points out the close crystallographic relation between rathite and dufrenoysite. I shall in my concluding paper on this group discuss the morphotropic relationship of the whole group.

There is a specimen of rathite labelled "arsenomelane" in the Museum of Practical Geology, London. The name "arsenomelane" was given by von Waltershausen, and he supplied material for the analyses of Uhrlaub and Nason: the results[1] of these analyses agree closely with the formula $3PbS.2As_2S_3$, and there can be little doubt that most of the "arsenomelane" found in 1855-7 was rathite.

Description of Specimens.

Habit I. Fig. 1, Plate III.

This habit was observed on eight small crystals. One very small crystal, Fig. 1, was especially good.

Thirty-seven forms were determined, viz.:—

a, b, $\frac{80}{3}r$, $18r$, $11r$, $9r$, $\frac{22}{3}r$, $6r$, $\frac{14}{3}r$, $4r$, $\frac{10}{3}r$, $3r$, $\frac{8}{3}r$, $\frac{7}{3}r$, $\frac{9}{4}r$, $2r$, $\frac{7}{4}r$, $\frac{5}{3}r$, $\frac{4}{3}r$, r, $\frac{3}{2}s$, $2s$, $3s$, $4s$, $7s$, $\frac{7}{3}k$, $\frac{5}{3}k$, k, $\frac{11}{3}q$, $3q$, $\frac{5}{2}q$, $\frac{7}{3}q$, $\frac{5}{3}q$, p, $2p$, $2m$, $\frac{3}{2}u$.

	Calculated.		Measured.	
010, 3.80.0	= 4°29′	...	4°27′ to 4°31′	narrow plane
, 1.18.0	= 6 37½	...	6 35 to 6 40	,,
, 1.11.0	= 10 46	...	10 44 to 10 47	,,
, 190	= 13 5	...	13 2 to 13 5	,,
, 3.22.0	= 15 55	...	15 52 to 15 56	,,
, 160	= 19 13	...	19 11 to 19 14	,,
, 3.14.0	= 24 8½	...	24 6 to 24 8	,,
, 140	= 27 36	...	27 32 to 27 38	,,
, 3.10.0	= 32 6	..	32 3 to 32 9	,,
, 130	= 34 52½	...	34 52 to 34 53	,,
, 380	= 38 6½	...	38 6 and 38 7	fairly large plane
, 370	= 41 52	...	41 50 to 41 52	narrow plane
, 490	= 42 54	...	42 51 to 42 57	,,
, 120	= 46 16½	...	46 16 and 46 18	large plane
, 470	= 50 4½	...	50 2 to 50 7	narrow plane
, 350	= 51 27	...	51 27	fairly large plane
, 340	= 57 29	...	57 30 and 57 32	large plane
, 110	= 64 26½	...	64 23 to 64 28	narrow plane
, 320	= 72 19	..	72 19	very large plane
, 210	= 76 33	...	76 25 to 76 40	narrow plane
, 310	= 80 56½	...	80 54 to 80 58	,,

[1] Min. Mag. XII, pp. 283 and 287, Nos. 17-20.

		Calculated.		Measured.	
010,	410	=83 11	...	83 8 to 83 14	narrow plane
,	710	=86 5½	...	86 to 86 10	,,
,	100	=90 0	...	90	small plane
010,	073	=39 59	...	39 58	narrow plane
,	053	=49 34	...	49 30	,,
,	011	=62 55½	...	62 57	small plane
010,	3.11.3	=37 59½	...	37 58 to 38	
,	131	=43 40	...	43 38 to 43 40	
,	353	=59 48	...	59 48 to 59 50	
,	111	=70 45	...	70 44 to 70 46	
100,	111	=46 25	...	46 24 to 46 26	
,	122	=64 33	...	64 30 to 64 36	
,	011	=90 0	...	89 58 to 90 1	
320,	111	=40 48	...	40 47	
,	353	=41 3	...	41 2	
340,	111	=40 39½	...	40 41	
,	353	=36 37	...	36 38	
350,	111	=41 52½	...	41 53	
,	353	=36 11½	...	36 13	
120,	111	=43 26½	...	43 30	
,	353	=36 30	...	36 32	

The forms 211, 132, 373, 252, 131, 3.11.3, 122 were determined by the following zones:—

211 [100, 111] [131, $\bar{1}$20]. 131 [010, 111] [320, $\bar{3}$53].
132 [131, 001] [010, 122]. 3.11.3 [010, 111] [340, $\bar{1}$11].
373 [010, 111] [320, $\bar{1}$11]. 122 [100, 111] [340, 353].
252 [010, 111] [130, 122].

There are also other minute pyramid planes which give no distinct reflections.

Habit II. Figs. 2 and 3.

This habit was observed on nine crystals; (010) (011) and (101) are largely developed, (010) is bright and smooth, (011) dull and finely striated parallel to the X axis, (101) with small (111) (313) (515) are rounded and deeply furrowed parallel to their mutual intersections, (320) (340) and (380) are largely developed.

Thirty-one forms were determined, viz. :—

a, b, c, $\frac{80}{3}r$, $9r$, $\frac{22}{3}r$, $\frac{17}{3}r$, $\frac{16}{3}r$, $\frac{14}{3}r$, $4r$, $\frac{10}{3}r$, $\frac{8}{3}r$, $2r$, $\frac{5}{3}r$, $\frac{4}{3}r$, $\frac{3}{2}s$, $3s$, $\frac{9}{2}s$, $7s$, $8s$, $7k$, $5k$, $\frac{7}{2}k$, $3k$, $\frac{8}{3}k$, $\frac{7}{3}k$, k, p, $3t$, $5t$, h.

	Calculated.		Measured.	
010, 3.16.0	=21°24½′	...	21°22′ to 21°25′	narrow plane
, 920	=83 56	...	83 52 to 83 58	,,
, 810	=86 35	...	86 30 to 86 40	,,
, 071	=15 37	...	15 34 to 15 40	,,
, 051	=21 22	...	21 20 to 21 26	,,
, 072	=29 12	...	29 14	,,
, 031	=33 6½	...	33 3 to 33 10	,,
, 033	=36 16	...	36 12 to 36 18	,,
, 313	=83 21½	...	83 to 83 30	rounded plane
, 515	=86 0	...	85 to 86	,,
, 101	=90 0	...	90 about	

The crystals belonging to this habit are always characterised by numerous twin lamellæ, according to law I (twin plane (074)).

	Calculated.		Measured.
010,074	=48°11′	...	47½° to 48½°

This angle was determined under a microscope fitted with cross wires and graduated circle. The crystals break parallel to (100), on which surface the lamellæ are well seen.

Very often small blade-shaped prisms are grown in twinned position on the prism planes of the principal crystal, according to law II (twin plane (0.15.1)). Triplets were also observed, according to law II (Fig. 2).

	Calculated.		Measured.
(010), ($\overline{010}$)	$=Z\overline{Z}=$14°52′	...	15°
($\overline{010}$), ($\overline{\overline{010}}$)	$=\overline{Z}\overline{\overline{Z}}=$29 44	...	30

The above angles were determined under a microscope by means of cross wires and a graduated circle.

One twinned crystal (Fig. 3) requires special notice. It is a juxtaposed twin, according to law II, and exhibits on the fractured surface of one crystal numerous twin lamellæ, according to law I.

The prisms are both well developed with (340) very large. On one crystal (072) gives a good reflection, (033) poor, and (073) rounded. The zone [010, 101] is rounded and deeply furrowed.

	Calculated.		Measured.
010, $\overline{010}$	=14°52′	...	14°55′
, 072	=29 12	...	29 14
010, $\overline{010}$	=14 52	...	14 50

This crystal consists of a number of similar crystals not quite parallel, as is seen when measuring round the prism zone.

Habit III. Fig. 4.

This habit was observed on three crystals. (010) is a narrow plane, while (320), (340), (120) and (380) are well developed. The brachydomes are well developed, and give good reflections. The twin lamellæ are not nearly so numerous as in habit II, and the parting plane (100) is *absent*.

Forty forms were observed, viz. :—

a, b, h, $\frac{80}{3}r$, $18r$, $11r$, $10r$, $8r$, $\frac{22}{3}r$, $7r$, $\frac{20}{3}r$, $6r$, $\frac{17}{3}r$, $\frac{16}{3}r$, $\frac{14}{3}r$, $4r$, $\frac{11}{3}r$, $\frac{10}{3}r$, $3r$, $\frac{8}{3}r$, $\frac{5}{2}r$, $\frac{7}{3}r$, $\frac{9}{4}r$, $2r$, $\frac{7}{4}r$, $\frac{5}{3}r$, $\frac{4}{3}r$, r, $\frac{3}{2}s$, $2s$, $4s$, $7s$, $7k$, $3k$, $\frac{7}{3}k$, $\frac{9}{5}k$, $\frac{5}{3}k$, $\frac{4}{3}k$, k, $\frac{5}{6}k$.

	Calculated.		Measured.	
010, 1.10.0	=11°49′	...	11°45′ to 11°50′	narrow plane
,, 180	=14 39	...	14 35 to 14 45	,,
,, 170	=16 38	...	16 35 to 16 45	,,
,, 3.20.0	=17 25	...	17 20 to 17 40	,,
,, 3.17.0	=20 15½	...	20 10 to 20 20	,,
,, 3.11.0	=29 42	...	29 40 to 29 45	,,
,, 250	=39 54½	...	39 50 to 40	,,
320, 3̄20	=35 22	...	35 22	sharp image
,, 340	=14 50	...	14 50	,,
340, 350	= 6 2	...	6 2	,,
350, 120	= 5 10½	...	5 10	,,
010, 071	=15 37	...	15 36	good image
,, 031	=33 6½	...	33 6	,,
,, 073	=39 59	...	39 58	,,
,, 095	=47 23	...	47 20 to 47 25	poor image
,, 053	=49 34	...	49 35	good image
,, 043	=56 20½	...	56 25	poor image
,, 011	=62 55½	...	62 55	fair image
,, 056	=66 55½	...	67	poor image

Habit IV.

This habit was observed on some large rough crystals given to me by Dr F. Grünling, of Munich. They resemble in form habit II, but exhibit no twin lamellæ. These crystals are of a dark steel-grey colour with splendid cleavage parallel to (010). On breaking up the crystals for analysis minute crystals were found lining some of the cavities. Some of the planes in the prism and brachydome zones were bright and large enough to measure.

Seventeen forms were observed, viz.:—

b, $18r$, $\frac{22}{3}r$, $\frac{16}{3}r$, $\frac{11}{3}r$, $3r$, $\frac{5}{2}r$, $2r$, $\frac{5}{3}r$, $\frac{3}{2}s$, $2s$, $3s$, $5k$, $\frac{7}{2}k$, $3k$, $\frac{8}{3}k$, $\frac{7}{3}k$.

Habit V. Fig. 5.

This habit was observed on one crystal. The crystal is in a cavity in the dolomite. It is a rounded prism with no definite terminations, with well-marked numerous twin lamellæ on the prism faces; only approximate measurements could be obtained, but they conform with twin law I. It is identical in appearance to crystal IV of Baumhauer. An untarnished prism of jordanite may easily be mistaken for a rathite of this habit.

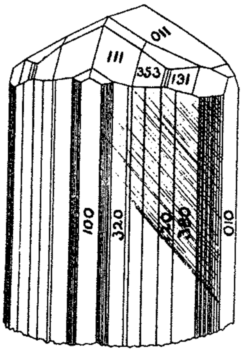

Fig. 1.

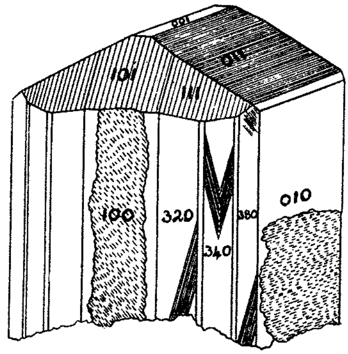

Fig. 2.

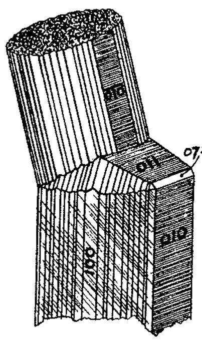

Fig. 3.

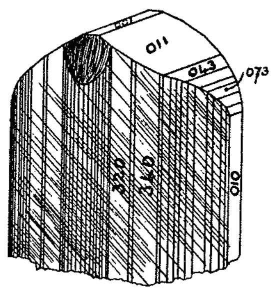

Fig. 4.

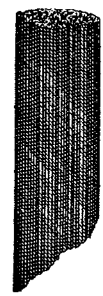

Fig. 5.

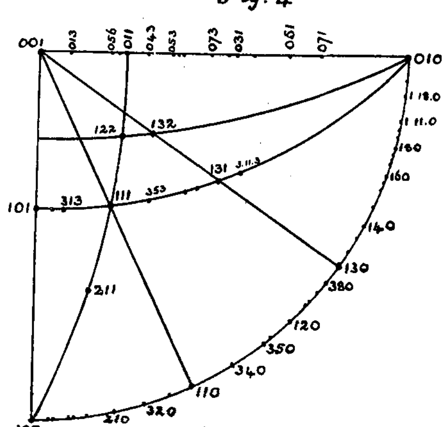

Fig. 6.

R. H. SOLLY: CRYSTALLOGRAPHY OF RATHITE.