CRYSTALLOGRAPHIC STUDIES OF SULPHOSALTS: BAUMHAUERITE, MENEGHINITE, JORDANITE, DIAPHORITE, FREIESLEBENITE

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WITH *X*-RAY STUDIES BY
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BAUMHAUERITE

Information regarding this mineral is confined to the paper of Solly (1903). The author measured two crystals and from the gnomonic plot of one of them discovered a typographical error in Solly's original statement of the axial ratio. This error did not affect the values of his angles but it has gone into every printed description of the mineral. Since no complete two-circle angle table has been published for baumhauerite, one has been calculated and the angles for the more important forms are given below; 118 forms are listed by Solly whose position and elements (corrected) have been used. The mineral is characterized by the enormous development of the orthodome zone to which belong two-thirds of the observed forms.

BAUMHAUERITE—$Pb_4As_6S_7$

Monoclinic; prismatic—$2/m$

$a:b:c=1.3687:1:0.9472;\ \beta=97°17'$
$p_0:q_0:r_0=0.6920:0.9396:1;\ \mu=82\ 43$
$r_2:p_2:q_2=1.0643:0.7365:1;$
$p_0'=0.6976,\ q_0'=0.9472;\ x_0'=0.1278$

Forms		ϕ	ρ	ϕ_2	$\rho_2=B$	C	A
c	001	90°00′	7°17′	82°43′	90°00′	0°00′	82°43′
b	010	0 00	90 00	—	0 00	90 00	90 00
a	100	90 00	90 00	0 00	90 00	82 43	0 00
F	520	61 29½	90 00	0 00	61 29½	83 36	28 30½
H	210	55 49½	90 00	0 00	55 49½	83 59	34 10½
K	320	47 51	90 00	0 00	47 51	84 36½	42 09
m	110	36 22½	90 00	0 00	36 22½	85 41½	53 37½
O	120	20 13	90 00	0 00	20 13	87 29½	69 47
k	011	7 41	43 42½	82 43	46 47	43 13	84 42
ι	702	90 00	68 44	21 16	90 00	61 27	21 16
κ	301	90 00	65 45½	24 14½	90 00	58 28½	24 14½
μ	502	90 00	61 53	28 07	90 00	54 36	28 07

BAUMHAUERITE—*Continued*

Forms	ϕ	ρ	ϕ_2	ρ_2=B	C	A
ξ 201	90 00	56 42½	33 17½	90 00	49 25½	33 17½
ρ 302	90 00	49 35	40 25	90 00	42 18	40 25
ψ 101	90 00	39 32	50 28	90 00	32 15	50 28
Λ 102	90 00	25 29	64 31	90 00	18 12	64 31
Π 103	90 00	19 49	70 11	90 00	12 32	70 11
Σ 104	90 00	16 49	73 11	90 00	9 32	73 11
Φ 106	90 00	13 43	76 17	90 00	6 26	76 17
g: $\bar{1}04$	−90 00	2 40	92 40	90 00	9 57	92 40
l: $\bar{1}02$	−90 00	12 27½	102 27½	90 00	19 44½	102 27½
q: $\bar{1}01$	−90 00	29 40½	119 40½	90 00	36 57½	119 40½
t: $\bar{3}02$	−90 00	42 34	132 34	90 00	49 51	132 34
w: $\bar{7}04$	−90 00	47 32½	137 32½	90 00	54 49½	137 32½
z: $\bar{2}01$	−90 00	51 43½	141 43½	90 00	59 00½	141 43½
C: $\bar{5}02$	−90 00	58 15	148 15	90 00	65 32	148 15
E: $\bar{3}01$	−90 00	63 01½	153 01½	90 00	70 18½	153 01½
p 111	41 04	51 29	50 28	53 51	46 56	59 04
o $\bar{1}11$	−31 02	47 52	119 40½	50 33	51 54	112 28½
n 122	26 42½	46 40½	64 31	49 28	43 46½	70 55
N $\bar{1}22$	−13 08	44 12½	102 27½	47 14	46 17½	99 07

Errata: Solly (1903) for $a=1.1368$ read 1.3687
Dana (1909) for $a=1.1368$ read 1.3687
Goldschmidt (1928) for $p_0'=0.8402$ read 0.6976;
for $e'=0.1305$ read 0.1278
for $p_0=0.8332$ read 0.6920;
for $\mu=82°34'$ read $82°43'$

REFERENCES

Dana, E. S., and Ford, W. E. (1909): Second Appendix to the Sixth Edition of Dana's System of Mineralogy, p. 13.

Goldschmidt, V., and Gordon, S. G. (1928): Crystallographic Tables for the Determination of Minerals—Special Publication No. **2**, *Acad. Nat. Sci. Philadelphia*, 44; No. 1089.

Solly, R. H. (1903): Baumhauerite—*Mineral. Mag.*, vol. **13**, p. 151, and *Zeits. Krist.*, vol. **37**, p. 321.

MENEGHINITE

Meneghinite has been found in definite crystals at but one locality, Bottino, Italy. Our knowledge of its crystallography rests upon studies made simultaneously by Krenner (1883) and Miers (1883), which established its orthorhombic character and yielded substantially the same elements. The two authors differed, however, in one respect. Miers found a series of typical forms with simple indices and with them additional forms of equally good quality to which he could only assign very complex indices. He insisted that these forms were to be regarded as true members of the form series. Krenner also observed such forms but regarded them as vicinal and discarded them. He pointed out that such vicinal forms accounted for the earlier erroneous monoclinic interpretation of the crystals by vom Rath (1867).

No further observations seem to have been made on meneghinite; but Ungemach (1923) discussed the form series, suggested a new choice of unit form and concluded that the aberrant forms might be best explained by regarding the mineral as monoclinic with concealed twinning, analogous to jordanite with which isomorphism had been suspected by several authors.

The author tested this theory by measuring crystals, and Mr. W. E. Richmond made an x-ray study which is reported below. The results of these studies are positive as to the orthorhombic character of meneghinite; a new unit cell is imperative which differs from that of any previous observer; the aberrant forms are confirmed but wholly unexplained; and the fact is established that it is not isomorphic with jordanite.

The crystals are slender needles with minute terminal facets. The acicular direction is taken as c by all observers. The new elements required by the x-ray measurements have the same directions as before, but the new unit (111) is the form (414) of Miers and (214) of Krenner. Transformations:—

Miers to Palache $\frac{1}{4}00/010/00\frac{1}{4}$
Krenner to Palache $\frac{1}{2}00/010/00\frac{1}{4}$

As the basis of the angle table, the author has employed the elements of Goldschmidt (1897), which are the mean of those of Miers and Krenner. Table 1 is therefore a restatement of Goldschmidt's angles with new indices for the forms; the letters have been preserved unchanged except for two prisms.

The author measured three crystals from the type locality. They show a prism zone so deeply grooved by striations that but a few typical faces could be recognized except the pinacoid parallel to which there is perfect cleavage. This face, always good, was taken as (010). The presence of basal cleavage was also verified, but both cleavages are obtained only with considerable difficulty. Table 2 shows the terminal faces found on two of the measured crystals.

TABLE 1. MENEGHINITE—$Pb_{13}Sb_7S_{23}$

Orthorhombic; dipyramidal—$m\ m\ m$

$a:b:c=0.4736:1:0.1715$; $p_0:q_0:r_0=0.3621:0.1715:1$

$q_1:r_1:p_1=0.4736:2.7617:1$; $r_2:p_2:q_2=5.8309:2.1114:1$

Forms		ϕ	$\rho=C$	ϕ_1	$\rho_1=A$	ϕ_2	$\rho_2=B$
c	001	—	0°00′	0°00′	90°00′	90°00′	90°00′
b	010	0°00′	90 00	90 00	90 00	—	0 00
a	100	90 00	90 00	—	0 00	0 00	90 00
e	160	19 23	90 00	90 00	70 37	0 00	19 23
R	140	27 49½	90 00	90 00	62 10½	0 00	27 49½
S	130	35 08	90 00	90 00	54 52	0 00	35 08
l	380	38 22	90 00	90 00	51 38	0 00	38 22
f	5.12.0	41 20	90 00	90 00	48 40	0 00	41 20
T	120	46 33	90 00	90 00	43 27	0 00	46 33
g	340	57 43	90 00	90 00	32 17	0 00	57 43
i	780	61 34½	90 00	90 00	28 25½	0 00	61 34½
m	110	64 39½	90 00	90 00	25 20½	0 00	64 39½
h	520	79 16½	90 00	90 00	10 43½	0 00	79 16½
k	310	81 01½	90 00	90 00	8 58½	0 00	81 01½
y	032	0 00	14 25½	14 25½	90 00	90 00	75 35½
d	021	0 00	18 56	18 56	90 00	90 00	71 04
o	083	0 00	24 35	24 35	90 00	90 00	65 25
v	041	0 00	34 27½	34 27½	90 00	90 00	55 32½
n	101	90 00	19 54½	0 00	70 05½	70 05½	90 00
W	403	90 00	25 46½	0 00	64 13½	64 13½	90 00
V	201	90 00	35 55	0 00	54 05	54 05	90 00
u	111	64 39½	21 50	9 44	70 21½	80 05½	80 50½
β	221	64 39½	38 42½	18 56	55 35	54 05	74 28½
t	121	46 33	26 30½	18 56	71 05½	80 05½	72 07½
s	131	35 08	32 11	27 14	72 09	80 05½	64 11
r	141	27 49½	37 48½	34 27½	73 22½	80 05½	57 10½
μ	211	76 40½	36 39½	9 44	54 29	54 05	82 05½
p	241	46 33	44 56	34 27½	59 09	54 05	60 56½
δ	0.24.13	0 00	17 34	17 34	90 00	90 00	72 26
φ	0.24.11	0 00	20 31½	20 31½	90 00	90 00	69 28½
q	24.0.11	90 00	38 19	0 00	51 41	51 41	90 00
λ	24.24.13	64 39½	36 29½	17 34	57 29½	56 14	75 15
σ	24.24.11	64 38½	41 09½	20 31	53 30	51 41	73 38

TABLE 1.—*Continued*

Forms		ϕ	$\rho=C$	ϕ_1	$\rho_1=A$	ϕ_2	$\rho_2=B$
ρ	24.48.11	46 33	47 25½	36 49	57 41	51 41	59 34½
ψ	24.48.13	46 33	42 38½	32 21	60 32½	56 14	62 14
X	24.72.13	35 08	49 16½	43 32	64 08½	56 14	51 42
π	24.96.13	27 49½	55 04½	51 42½	67 30	56 14	43 31
ω	7.21.1	35 08	77 12½	74 29	55 52	21 32	37 06

TABLE 2. MEASUREMENTS OF MENEGHINITE

Crystal 1	Measured ϕ	Measured ρ	Calculated ϕ	Calculated ρ	Quality
010	0°00′	90°00′	0°00′	90°00′	excellent
0.24.11	0 00	20 07	0 00	20 31½	good
121	46 37	26 35	46 33	26 30½	excellent
24.24.13	64 32	36 40	64 39½	36 29½	poor—end of chain
Crystal 2					
010	0 00	90 00	0 00	90 00	excellent
041	0 02	34 36	0 00	34 27½	excellent
0.24.11	0 02	20 35	0 00	20 31½	good
111	65 16	21 36	64 39½	21 50	very poor
121	46 22	26 52	46 33	26 30½	poor
131	35 09	32 11	35 08	32 11	excellent
141	28 04	38 00	27 49½	37 48½	poor
$\bar{1}41$	−28 00	37 55	−27 49½	37 48½	good
211	76 45	37 10	76 40½	36 39½	very poor
$\bar{2}11$	−76 32	37 00	−76 40½	36 39½	very poor
241	46 22	43 35	46 33	44 56	very poor
24.24.13	65 16	36 44	64 39½	36 29½	poor
$\overline{24}$.24.13	−64 32	36 34	−64 39½	36 29½	good
24.24.11	65 16	41 31	64 39½	41 09½	poor
$\overline{24}$.24.11	−64 32	41 04	−64 39½	41 09½	poor
24.48.13	46 32	42 50	46 33	42 38½	excellent
7.21.1	35 32	77 12	35 08	77 12½	poor
7.21.1	35 09	76 43	−35 08	77 12½	poor

This table shows clearly that each of these crystals has faces of both normal and aberrant forms, intermingled and all in good position. There is no difference observable in quality between them and in no way could one say that one set was more typical than the other. All the faces are so minute that it is difficult to observe the actual crystal surfaces. It is noteworthy that the aberrant forms are displaced by small angular distances, from faces of simple indices but always in a radial relation, the ϕ angles being alike. It is difficult to picture this relation as being due to any type of twinning.

Two new forms were noted as shown in the table, (0.24.11) and (7.21.1), each with two faces. They are simply to be added to the list of aberrant forms. *Q* and *w*, listed in Miers from vom Rath are omitted as very uncertain.

The third crystal measured showed no trace of aberrant forms but yielded a characteristic series in good position, including (010), (100), (140), (380), (120), (110), (021), (041), (101), (111), (121), (131), and (141).

Structural Lattice of Meneghinite

by W. E. Richmond

The structural lattice was determined from rotation and Weissenberg photographs about the needle axis [001]. The lattice constants computed from the *x*-ray photographs are:

$$a_0 = 11.29;\ b_0 = 23.78;\ c_0 = 4.12$$

giving the ratio:—

$a:b:c = 0.4750:1:0.1733$ in close agreement with the morphological ratio:—

$$a:b:c = 0.4736:1:0.1715.$$

The volume of the unit cell $V_0 = 1103$; with the specific gravity 6.358 (vom Rath) this gives a molecular weight for the unit cell of $M_0 = 4162$.

The content of the unit cell. The analysis of meneghinite by vom Rath has the smallest amount of impurity, so is made the basis of the calculation as shown in the following table.

TABLE 3. ANALYSIS OF MENEGHINITE

	1	2	3	4	5	6
Pb	61.47	63.75	.308	13.08	63.92	62.88
Sb	18.37	19.05	.156	6.68	18.77	19.91
S	16.97	17.20	.537	22.85	17.31	17.21
Cu	0.39					
Fe	0.23					
Ins.	0.82					
	98.25	100.00			100.00	100.00

1. Meneghinite from Bottino, Italy. Vom Rath, analyst.
2. Recalculated to 100% after deducting $CuFeS_2$ and insoluble.
3. Atomic proportions of 2.
4. Atomic content of unit cell.
5. Calculated composition of formula $Pb_4Sb_2S_7$.
6. Calculated composition of formula $Pb_{13}Sb_7S_{23}$.

The figures of column 4 yield the formula $Pb_{13}Sb_7S_{23}$, replacing the old accepted formula $Pb_4Sb_2S_7$. The density calculated for this formula is 6.391, which compares favorably with the value of vom Rath, 6.358.

REFERENCES

Goldschmidt, V. (1897): Winkeltabellen, p. 238.
Krenner, J. A. (1883): *Folt. Közl.*, vol. **13**, pp. 297 and 350.
Miers, H. A. (1883): *Mineral. Mag*, vol. **5**, p. 325.
vom Rath, G. (1867): *Ann. Phy. & Chem.*, vol. **132**, p. 372.
Ungemach, H. (1923): *Zeits. Krist.*, vol. **58**, p. 158.

JORDANITE

The latest account of jordanite is contained in the paper by Solly (1900), in which he traces the history of the mineral to that time and adds new forms to the already long lists of Baumhauer. Solly employs the position and elements of the latter, namely:

$$a:b:c=0.4945:1:0.2655 \quad \beta=90°33\tfrac{1}{2}'$$

The author measured two crystals from the type locality, confirming the angles and many of the forms of earlier observers and adding five new forms. The crystals were measured with (010) as pole, and the gnomonic projection at once suggested both to the author and to Dr. Peacock a possible better choice of orientation of the axes. The choice finally made by Peacock on a morphological basis was confirmed, as is shown below, by x-ray study and is accepted as the proper setting.

The new axial ratio, calculated from the old, is:

$$a:b:c=0.2354:1:0.1397 \quad \beta=93°53'$$

and its position is related by the transformations

Baumhauer to Peacock	$\bar{1}03/0\bar{4}0/101$
Peacock to Baumhauer	$\bar{1}03/010/101$

This is equivalent to taking (100) Baumhauer as ($\bar{1}$01)
(010) Baumhauer as (0$\bar{1}$0)
(001) Baumhauer as (301)

Twinning referred to the new axes is most common on {100} and is often lamellar, yielding a surface of parting; it is common on {001}, rare on {101} and vary rare on {$\bar{3}$01}.

Cleavage is parallel to {010}, which is the direction of dominant tabular development.

The following forms of Solly's list are omitted, being regarded as vicinal to closely neighboring forms:

Form Solly	Palache	Vicinal to	Diff. in angle to (010)
(12.49.0)	($\bar{3}$.49.3)	($\bar{1}$.16.1)	28 minutes
(9.32.0)	($\bar{9}$.128.9)	($\bar{1}$.14.1)	23 minutes
(7.24.0)	($\bar{7}$.96.7)	($\bar{1}$.14.1)	31 minutes
(047)	(21.16.7)	(321)	84 minutes
($\overline{28}$.3.28)	(28.3.0)	(910)	3 minutes

The following forms are added to the list on the basis of the author's observations:

Symbol Palache	Solly	Measured ϕ	Measured ρ	Calculated ϕ	Calculated ρ
(091)	(391)	85°57′	38°30′	86°07′	38°33½′
		86 09	38 32		
(183)	(221)	74 52	70 32	75 05½	70 12
(1.54.1)	(1.28.1)	56 37	9 42	56 28	9 02
($\bar{3}$.14.1)	($\bar{3}$71)	150 04	45 19	149 46½	45 27
($\bar{3}$.16.1)	($\bar{3}$81)	150 00	41 37	149 46½	41 38

Because no complete angle table has been calculated for jordanite since it was determined to be monoclinic, the author has calculated such a table and gives herewith some of the more important forms. There are 115 forms known.

TABLE 1. JORDANITE—$Pb_{14}As_7S_{24}$

Monoclinic; prismatic—$2/m$
$a:b:c=0.2354:1:0.1397;\ \beta=93°53'$
$p_0:q_0:r_0=0.5935:0.1394:1;\ \mu=86°07'$
$r_2:p_2:q_2=7.1747:4.2579:1;$
$p_0'=0.5948,\ q_0'=0.1397;\ x_0'=0.0679$

Forms	ϕ	ρ	ϕ_2	ρ_2=B	C	A
b 010	0°00′	90°00′	—	0°00′	90°00′	90°00′
a 100	90 00	90 00	0°00′	90 00	86 07	0 00
J 180	28 01½	90 00	0 00	28 01½	88 10½	61 58½
L 160	35 21½	90 00	0 00	35 21½	87 45	54 38½
M 150	40 25	90 00	0 00	40 25	87 29	49 35
Q 130	54 50	90 00	0 00	54 50	86 50	35 10
S 120	64 50½	90 00	0 00	64 50½	86 29	25 09½
n: 101	90 00	33 32	56 28	90 00	29 39	56 28
q: $\bar{1}$01	−90 00	27 47	117 47	90 00	31 40	117 47
s: $\bar{3}$01	−90 00	59 46½	149 46½	90 00	63 39½	149 46½
U 123	70 43	15 45	75 05½	84 51½	13 59	75 09½
W 163	43 37	21 06	75 05½	74 53½	19 51	75 37
p 111	78 06	34 06½	56 28	83 21½	30 19	56 43½
i 141	49 51½	40 55	56 28	65 01½	38 01	59 57
l 161	38 20	46 54	56 28	55 03½	44 34	63 04½
n 181	30 40	52 25	56 28	47 01½	50 31	66 09½
t 1.12.1	21 34	60 59	56 28	35 35½	59 37	71 15
ϵ $\bar{1}$21	−62 04	30 48½	117 47	76 07	34 17	116 54½
ι $\bar{1}$41	−43 19	37 31½	117 47	63 41½	40 16½	114 42
λ $\bar{1}$61	−32 09	44 43	117 47	53 26½	46 52½	111 59½
υ $\bar{1}$81	−25 14½	51 01	117 47	45 19½	52 45½	109 21½
ρ $\bar{1}$.10.1	−20 40	56 11	117 47	38 58½	57 38	107 03
τ $\bar{1}$.12.1	−17 27	60 21½	117 47	33 59½	61 35½	105 06½

STRUCTURAL LATTICE OF JORDANITE

by W. E. RICHMOND

The structural lattice was determined from rotation and zero-layer Weissenberg photographs about the axis [010]. The lattice constants computed from the x-ray photographs are:

$$a_0=7.529\text{Å},\ b_0=31.87\text{Å},\ c_0=4.421\text{Å};\quad \beta=93°59'$$

giving the axial ratio:

$$a_0:b_0:c_0=0.2362:1:0.1387; \quad \beta=93°59'$$

in close agreement with the morphological ratio:

$$a:b:c=0.2354:1:0.1397; \quad \beta=93°53'$$

The volume of the unit cell, V_0, is 1058.1 cubic Ångstroms; with the specific gravity 6.413 (Jackson) this gives a molecular weight for the unit cell of $M_0=4103.2$; with specific gravity 6.32 (new determination) $M_0=4053$.

Using the analysis of Jackson (Solly, 1900), we obtain the figures of Table 2 for the probable content of the unit cell.

TABLE 2. ANALYSIS OF JORDANITE

	1	2	3	4	5	6
Pb	68.61	69.22	.334	13.78	13.53	14 or 13
S	18.19	18.36	.577	23.67	23.38	24 or 23
As	12.32	12.42	.166	6.81	6.73	7
	99.12	100.00				

1. Jordanite from Binn. Jackson, analyst.
2. Recalculated to 100%.
3. Atomic proportions of 2.
4. Atomic content of unit cell using $G=6.413$.
5. Atomic content of unit cell using $G=6.32$.
6. Rounded out atomic numbers.

The figures show little choice between the formulae $Pb_{14}As_7S_{24}$ and $Pb_{13}As_7S_{23}$. We are inclined to select the former. Table 3 shows the calculated composition and density of both formulae as well as of the generally accepted one of $Pb_4As_2S_7$.

TABLE 3. CALCULATED COMPOSITION AND DENSITY OF VARIOUS FORMULAE OF JORDANITE

	$Pb_{14}As_7S_{24}$	$Pb_{13}As_7S_{23}$	$Pb_4As_2S_7$
Pb	69.20	68.13	68.90
S	18.34	18.61	18.65
As	12.46	13.26	12.45
	100.00	100.00	100.00
G	6.54	6.17	5.63

Our inclination is to assign to jordanite the formula $Pb_{14}As_7S_{24}$. If, however, the alternative formula were selected, the chemical identity with meneghinite would be preserved and the two minerals would be dimorphous. New chemical work will be needed before the final decision on this matter can be made.

Reference

Solly, R. H. (1900): Jordanite, *Mineral. Mag.*, vol. **12**, p. 290. Analysis by Jackson, same page 289.

Diaphorite

Diaphorite was described by Zepharovich in 1871 as an orthorhombic mineral with the same composition as freieslebenite and nothing of importance has been added since the original description. A specimen of diaphorite from Freiberg in the Karabachek collection yielded a wealth of new data and the results of its study are here presented. Eight crystals were measured in all, four from the new specimen and four from older specimens in the Harvard collection. The latter were similar to the type description and one of them was a twin on the recognized law, twin plane {120}. The crystals from the Karabachek specimen were highly complex in development; one presented one hundred and fourteen faces representing fifty six forms; and by their study more than fifty new forms were added to the twenty four previously known.

On morphological grounds a new fundamental pyramid was selected which was the pyramid {114} of Zepharovich and this choice was confirmed by Winchell's x-ray study presented on a later page. The transformation Zepharovich to Palache is $100/010/00\frac{1}{4}$.

New elements were calculated from the measurements of fifty faces of twenty-five forms on eight crystals.

$$a:b:c = 0.4953:1:0.1840$$

$$p_0:q_0:r_0 = 0.3715:0.1840:1$$

This ratio is closely comparable with that of Zepharovich,

$$a:b:\tfrac{1}{4}c = 0.4919:1:0.1838$$

The table following presents the observations made on these crystals in condensed form, the calculated angles being based on the new elements. The known forms were all found with the exception of the following five:—

		ϕ	ρ	
α	1.11.0	10°24′	90°00′	
k	5.12.0	40 04	90 00	
q	0.20.3	0 00	50 48½	(probably vicinal to {071}, a form missing in the series of domes with $\rho = 52°10\frac{1}{2}'$)
d	141	26 47	39 30	
ζ	241	45 16	46 17	

Diaphorite
Table of Calculated and Observed Angles

		Calculated		Observed, mean		Range		No. of		
		ϕ	ρ	ϕ	ρ	ϕ	ρ	faces	Crysts.	Qual.
*c	001	°—′	0°00′	°—′	0°00′	° ′ ° ′	—	3	3	fair
b	010	0 00	90 00	0 06	90 00	0 00 – 0 16	—	6	4	poor
a	100	90 00	90 00	89 50	90 00	89 27 –90 00	—	7	7	good
*β	170	16 05½	90 00	16 39	90 00	16 08 –17 10	—	2	2	poor
*γ	160	18 36	90 00	18 36½	90 00	18 25 –18 48	—	2	2	good
ρ	150	21 59	90 00	22 07	90 00	22 00 –22 12	—	3	3	fair
*σ	140	26 47	90 00	26 32	90 00	25 55 –27 10	—	2	2	poor
π	130	33 56	90 00	33 57	90 00	33 45 –34 08	—	11	5	fair
n	120	45 16	90 00	45 12	90 00	44 43 –45 34	—	13	8	good
*ε	230	53 23	90 00	53 43	90 00	—	—	1	1	good
m	110	63 39	90 00	63 40	90 00	63 05 –64 00	—	14	8	good
*χ	320	71 43½	90 00	71 40	90 00	71 30 –71 49	—	2	1	good
*δ	210	76 05½	90 00	76 27½	90 00	76 25 –76 30	—	2	2	poor
t	310	80 37½	90 00	81 52	90 00	81 17 –82 27	—	2	1	poor
*h	011	0 00	10 25½	0 00	9 01	—	—	1	1	fair
u	021	0 00	20 12	0 00	20 18	—	20°00′–21°00′	8	5	poor
r	041	0 00	36 21	0 00	36 32	—	36 15 –36 41	6	4	good
v	061	0 00	47 50	0 00	47 36	—	47 32 –47 42	2	2	fair
w	081	0 00	55 48½	0 00	55 50	—	55 28 –56 09	12	8	good
*f	0.10.1	0 00	61 28½	0 00	61 28	—	61 15 –61 43	5	3	fair
*g	0.12.1	0 00	65 38	0 00	65 38½	—	65 15 –66 47	3	2	fair
*j	0.14.1	0 00	68 47	0 00	68 38	—	—	1	1	good
ψ	201	90 00	36 36½	90 00	36 30½	—	36 11 –36 47	7	6	good
x	401	90 00	56 03½	90 00	56 07	—	55 52 –56 15	7	6	good
*A	112	63 39	11 42½	63 57	11 47	63 32 –64 22	11 34 –12 00	2	2	poor
i	111	63 39	22 31	63 54	22 34	63 32 –64 27	22 06 –23 03	8	4	good
*B	332	63 39	31 52½	63 45	31 43	63 38 –63 53	31 41 –31 45	3	2	fair
y	221	63 39	39 39½	63 37	39 42	63 04 –64 22	39 28 –40 02	13	8	good
*C	331	63 39	51 12	63 35½	51 21	63 22 –63 53	51 00 –51 53	5	4	fair
*D	441	63 39	58 54½	63 50	58 48	63 47 –63 53	58 47 –58 49	2	2	poor
*E	551	63 39	64 14½	63 58	64 11½	63 53 –64 01	64 00 –64 41	4	3	poor
*F	133	33 56	12 30½	33 45	12 44	33 10 –34 20	12 42 –12 46	2	1	poor
*G	173	16 05	24 04½	16 40	24 27	16 25 –16 55	24 12 –24 42	2	2	very good
*H	132	33 56	18 24	33 52	18 34	33 11 –34 20	18 20 –18 48	3	2	fair
*J	172	16 05	33 50	16 17½	33 52	15 47 –16 50	33 43 –34 05	5	2	fair
*K	192	12 38½	40 19	12 45	40 26½	12 23 –13 07	40 07 –40 33	4	2	good
*L	283	26 47	28 47½	26 31	28 46	26 18 –26 56	28 38 –28 55	3	3	poor
M	2.22.3	10 24	53 54½	10 00	54 00	—	—	1	1	good
o	131	33 56	33 38½	34 00	33 38	33 55 –34 03	33 30 –33 50	4	4	very good
*N	151	21 59	44 46½	22 00	44 39	21 50 –22 16	44 16 –44 56	3	2	poor
*O	171	16 05	53 16½	16 04½	53 19	15 40 –16 50	53 00 –53 39	8	3	fair
*P	191	12 38½	59 29½	12 38	59 29	12 16 –12 59	59 20 –59 26	3	2	good

DIAPHORITE—*Continued*

		Calculated ϕ	Calculated ρ	Observed, mean ϕ	Observed, mean ρ	Range ϕ	Range ρ	No. of faces	Crysts.	Qual.
*Q	1.11.1	10 24	64 05	10 29	64 07½	10 20 –10 38	64 05 –64 10	2	2	good
*R	1.13.1	8 49½	67 33	8 35	67 56	8 30 – 8 40	67 52 –68 00	2	2	poor
*S	312	80 37½	29 27½	80 33½	29 57	80 27 –80 40	29 35 –30 19	2	2	poor
*T	352	50 27½	35 51	50 34	35 48½	50 12 –50 56	35 40 –35 57	2	2	poor
*U	392	33 56	44 56½	34 03	44 53	34 02 –34 05	44 28 –45 05	3	3	poor
*V	211	76 05½	37 25½	76 02	37 30	—	—	1	1	poor
*η	251	38 55½	49 47	38 55	49 40	—	—	1	1	poor
*θ	261	33 56	53 04½	33 59½	53 04½	33 38 –34 20	52 33 –53 18	7	3	good
*ι	281	26 47	58 46	26 46	58 44	26 38 –26 50	58 40 –58 50	3	2	good
*κ	2.10.1	21 59	63 15	21 58	63 29	21 50 –22 16	63 06 –63 47	6	3	poor
*λ	2.12.1	18 36	66 46	18 47½	66 37½	18 40 –18 48	66 22 –66 53	3	2	poor
*μ	2.14.1	16 05	69 32½	16 04	69 25	16 00 –16 08	69 00 –69 50	2	2	good
ω	311	80 37½	48 28½	80 32½	48 30	80 16 –80 43	48 17 –48 42	5	4	poor
*ν	351	50 27½	55 19	50 26	55 22	50 12 –50 35	55 00 –55 42	3	3	fair
*ξ	391	33 56	63 23½	34 07½	63 21	34 02 –34 20	62 52 –63 45	4	3	good
*τ	3.13.1	24 59	69 14½	24 54	69 07	24 54 –25 02	69 00 –69 14	2	2	good
*φ	712	85 57	52 30	86 13	52 50	85 55 –86 32	52 36 –52 57	3	2	poor
z	421	76 05½	56 50½	76 08	56 54	75 50 –76 20	56 30 –57 00	5	4	very good
*W	431	69 37	57 45	68 40	57 58	68 31 –68 50	57 56 –58 00	2	2	fair
*X	4.16.1	26 47	73 08	26 56	72 56½	26 46 –27 02	72 35 –73 18	4	2	poor
*Z	511	84 20½	61 49	84 12	62 05	83 56 –84 31	61 55 –62 13	3	2	very good
e	531	73 27	62 42	73 30½	62 48½	73 20 –73 45	62 30 –63 12	12	6	good
*Δ	621	80 37½	66 07½	80 42	66 07	80 34 –80 52	66 00 –66 15	4	3	very good
*Λ	641	71 43½	66 55½	71 44	67 03	71 40 –71 48	66 46 –67 20	2	2	good
*Ξ	711	85 57	69 00½	86 08	69 30	86 06 –86 09	69 21 –69 40	2	2	good
*Σ	731	78 01	69 23	78 01½	69 38½	77 55 –78 22	69 30 –69 47	3	3	good
*Θ	841	76 05½	71 54½	76 24	72 05	76 21 –76 26	71 45 –72 19	3	2	fair
*Υ	971	68 56	74 24	68 57	74 32	—	—	1	1	good
*Ω	10.2.1	84 20½	75 00	84 40	75 18	—	—	1	1	very good
*Ψ	16.2.1	86 27½	80 28	86 12	80 26	—	—	1	1	very good

* Denotes new form.

The prism zone is strongly developed and is striated but distinct faces of {100}, {130}, {120}, and {110} are nearly always present. The termination is generally dominated by some or all of the domes {021}, {041}, {081}, {201}, and {401}. The only pyramids commonly present are {221} and {531}. The crystals are minute and the faces are in most cases not sharply outlined. Nevertheless the angles, as shown in the table, are very consistent and the signals were good for such small faces.

X-RAY STUDY OF DIAPHORITE AND FREIESLEBENITE
by HORACE WINCHELL

In order to better establish the relationship between the two minerals diaphorite and freieslebenite, long held to be dimorphous, an x-ray study was undertaken, employing crystals studied goniometrically, and including a discussion of their chemical character in view of the structural results.

Diaphorite. Weissenberg photographs about the b and c axes, on the zero and the first layers were studied, as well as rotation photographs about all three axes, using $Cu_{K\alpha}$ radiation. The axial lengths as given below were derived from weighted averages in which the higher order values received the greatest weight.

$$a_0 = 15.83\ \text{Å},\ b_0 = 32.23\ \text{Å},\ c_0 = 5.89\ \text{Å}$$
$$a_0 : b_0 : c_0 = 0.491 : 1 : 0.183$$

This ratio agrees well with the morphological value given above and confirms the choice of the unit form.

The volume of the unit cell, $V_0 = 3007$ cubic Ångstroms, with the mean observed value of the density, 5.97, gives for the molecular weight of the unit cell $M_0 = 10879$.

The following space group criteria were derived from the zero and first layer Weissenberg photographs about the c axis, and the zero layer about the a axis:—

hkl present only for k even
$hk0$ present only for h and k even
$h0l$ present only for h even
$0kl$ present only for k even

which defines the space group as $D_{2h}^{21}(Cmma)$.

There are two authentic analyses of diaphorite, both on material from Pribram.

	1	2	3	4	5	6	7
Cu	0.73	0.011					
Fe	0.67	0.012	26.11	23.36	0.216	23.52	23.80
Ag	23.44	0.217					
Pb	28.67	0.138	15.01	31.56	0.152	16.56	30.48
Sb	26.43	0.217	23.60	25.92	0.213	23.20	26.86
S	20.18	0.629	68.40	18.51	0.578	62.90	18.87
	100.12			99.35			100.01

1. Analysis by Helmhacker, 1864.
2. Atomic ratios.
3. Number of atoms in unit cell calculated from M_0.
4. Analysis by Moranski, 1878.
5. Atomic ratio.

6. Atoms in unit cell.
7. Calculated composition for $Ag_3Pb_2Sb_3S_8$.

The mean of the numbers in columns 3 and 6 when rounded out may be taken as 24:16:24:64 or 8 (3:2:3:8) which lead to the formula $Ag_3Pb_2Sb_3S_8$, with 8 molecules in the unit cell.

Freieslebenite. No new data on the morphology of this mineral were obtained. A single measurable crystal was found on a specimen from Hiendelencina, Spain, which confirmed the published angles. This crystal was used for the x-ray study. Rotation photographs about b and c, and Weissenberg photographs of the zero and first layers about c were obtained. The cell dimensions obtained are:—

$$a_0=7.53\text{Å},\quad b_0=12.79\text{Å},\quad c_0=5.88\text{Å},\quad \beta=92°14' \text{ (morphologic)}$$
$$a_0:b_0:c_0=0.589:1:0.460$$
$$a:b:c=0.5871:1:0.9277 \qquad \beta=92°14' \text{ (Miller)}$$

It follows that c must be halved and the transformation formula, Miller to Winchell reads $100/010/00\frac{1}{2}$

The volume of the unit cell, $V_0=567$ cubic Ångstroms; the specific gravity is 6.23 (Payr), 6.20 (Winchell); these values give as the molecular weight of the unit cell, $M_0=2145$.

The space group of freieslebenite is derived from the following systemic criteria:—

hkl present in all orders
$h0l$ present only for h even
$0k0$ present only for k even

Assuming that the crystal class is holohedral the space group is $C_{2h}^5(P2_1/n)$.

The only chemical analysis of freieslebenite which is accompanied by a density determination consistent with our data is that of Payr (1860) made on material from Pribram.

	1	2	3
Fe	0.63	0.11	4.83
Ag	23.08	.214	
Pb	30.77	.148	3.11
Sb	27.11	.223	4.78
S	18.41	.574	12.31
	100.00		25.03

1. Analysis by Payr; density 6.23.
2. Atomic ratios.
3. Number of atoms in the unit cell.

The numbers in column 3 approximate a total of 25 atoms and justify the formula $Ag_5Pb_3Sb_5S_{12}$, with one molecule in the unit cell.

SUMMARY TABLE

	Diaphorite	Freieslebenite
Formula	$8(Ag_3Pb_2Sb_3S_8)$	$Ag_5Pb_3Sb_5S_{12}$
Symmetry	orthorhombic	monoclinic
	a_0 15.83 Å	a_0 7.53 Å
X-ray elements	b_0 32.23 Å	b_0 12.79 Å
	c_0 5.89 Å	c_0 5.88 Å
Axial ratio	$a:b:c=.4953:1:.1840$	$a:b:c=.5871:1:.4638$
		$\beta=92°14'$
Specific gravity measured	5.90–6.04	6.20–6.23
Specific gravity calculated	5.97	6.27

The crystallographic and other physical properties of the two minerals considered in this study are shown to be in greater contrast than was before evident; the chemical differences are believed to be real and seem to disprove the supposed dimorphism. Need for new analyses on material physically studied is evident before a final decision can be reached.