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ART. IV.—*On Pearceite, a Sulpharsenite of Silver and on the Crystallization of Polybasite;* by S. L. PENFIELD.

1. *Pearceite.*

THE mineral to be described as pearceite in the present article is a sulpharsenite of silver, Ag_9AsS_6 or $9Ag_2S, As_2S_3$, analogous to polybasite Ag_9SbS_6, and like the latter characterized by having a part of the silver replaced by copper and often by small quantities of zinc and iron. It can not be claimed to be a *new mineral*, for as an arsenical variety of polybasite it has previously been recognized although no special name has been assigned to it. H. Rose[*] first described polybasite and gave the name to the species in 1828, and in 1833 he published[†] an analysis of a specimen from Schemnitz containing arsenic, with only a trace of antimony, while in the original polybasite from Durango, Mexico, described by him, both antimony and arsenic were present, and he recognized the fact that these elements were isomorphous and could mutually replace one another. The polybasites from Durango in Mexico, Freiberg in Saxony, Pribram in Bohemia, the Two Sisters' mine near Georgetown, the Yankee Boy mine near Ouray, and the Sheridan mine near Telluride in Colorado, the Comstock Lode in Nevada, and apparently from most localities, are essentially the antimony variety, and in mineralogical literature the composition of polybasite is usually given as a *sulphantimonite* of silver. Rammelsberg[‡] gives an analysis by Joy of polybasite from Cornwall, England, where antimony and arsenic are present in about equal molecular proportions, and the author in connection with Mr. Stanley H. Pearce, has published[§] analyses of arsenical polybasite (*pearceite*) from the Mollie Gibson mine, Aspen, Colorado. This latter material was not distinctly crystallized, but was found in great quantity and was the mineral which carried the bulk of the silver in the most productive silver mine in Colorado at that time.

The author's attention has recently been called to the occurrence of beautifully crystallized pearceite, or arsenical polybasite from the Drumlummon mine, Marysville, Lewis and Clarke Co., Montana. The mineral was first sent by Mr. R. F. Bayliss, of the Montana Mining Co., to Dr. Richard Pearce, of Denver, with the request that it should be investigated, and

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[*] Pogg. Ann., xv, p. 573, 1829.

[†] Loc. cit.. xxviii, p. 56, 1833.

[‡] Mineralchemie, p. 102, 1860.

[§] This Journal, xliv, p. 15, 1892.

the following analysis was made by Mr. F. C. Knight under Dr. Pearce's immediate supervision.

	Found.		Ratio.		Theoretical composition where $Ag_2 : Cu_2 : Fe = 255 : 143 : 19$.
S	17·71 ÷ 32 = ·553			11·95	17·96
As	7·39 ÷ 75 = ·098			2·11	7·02
Ag	55·17 ÷ 216 = ·255		·417	9·00	55·61
Cu	18·11 ÷ 127 = ·143				18·34
Fe	1·05 ÷ 56 = ·019				1·07
Insol.	·42				
	99·85				100·00

Dr. Pearce recognized that the mineral belonged to the polybasite class, where arsenic played the role usually taken by antimony, and forwarded the specimens, together with the analysis, to the author for an expression of opinion. As may be seen from the ratio, the proportion of S : As : (Ag_2+Cu_2+Fe) is very nearly 12 : 2 : 9, which is that demanded by the polybasite formula, and taking the metals in the same proportion as they are found in the analysis, $Ag_2 : Cu_2 : Fe = 255 : 143 : 19$, and calculating the theoretical composition, results agreeing very satisfactorily with the analysis are obtained.

Although recognizing that antimony and arsenic are isomorphous and may mutually replace one another, it is customary and has been found convenient in mineralogy to consider the sulphantimonites and sulpharsenites as distinct species, and to designate them by different names, and the author proposes that hereafter the name polybasite shall be restricted to the antimony compound Ag_9SbS_6, and to make of the corresponding arsenic compound Ag_9AsS_6 a distinct species. For the arsenical mineral he takes pleasure in proposing the name *pearceite* as a compliment to his friend, Dr. Richard Pearce, of Denver, whose keen interest in mineralogy and connection with one of the large smelting and refining works of Colorado have made him known both to scientific men and to those interested in the development of the mining industries of the Rocky Mountain region. The author furthermore takes pleasure in expressing his thanks to Mr. Bayliss, who has taken a great interest in the investigation and naming of the mineral, and has most generously placed at his disposal all of the available material.

It seems best to give at this point the analyses of pearceite, already referred to, which have previously been published as arsenical varieties of polybasite. In the theoretical composition given with each the ratio of the metals is the same as in the accompanying analysis.

I. H. Rose, $Ag_2 : Cu_2 : Zn : Fe = 335 : 24 : 9 : 6$.
II. Penfield, after deducting 12·81 per cent of impurities, mostly PbS, $Ag_2 : Cu_2 : Zn = 263 : 117 : 43$.
III. S. H. Pearce, after deducting 28·18 per cent of impurities, mostly PbS, $Ag_2 : Cu : Zn = 276 : 102 : 49$.

	I.		II.		III.		Theory for
	Schemnitz.	Theory.	Aspen, Colo.	Theory.	Aspen.	Theory.	Ag_9AsS_6.
S	16·83	16·19	18·13	18·13	17·73	18·02	15·50
As	6·23	6·32	7·01	7·08	6·29	7·03	6·05
Sb	0·25	----	·30	----	0·18	----	----
Ag	72·43	73·47	56·90	57·07	59·73	59·06	78·45
Cu	3·04	3·08	14·85	14·91	12·91	12·77	----
Zn	0·59	0·60	2·81	2·81	3·16	3·12	----
Fe	0·33	0·34	----	----	----	----	----
	99·70	100·00	100·00	100·00	100·00	100·00	100·00

Crystallization.

The crystallization of pearceite is *monoclinic* but with a close approximation to rhombohedral symmetry. The habit is commonly hexagonal with the basal planes prominent and the zones of bevelling forms between them often highly modified. The material from which crystallographic data could be obtained came wholly from a single specimen where the crystals were implanted upon a gangue of quartz and imbedded in calcite, and were obtained by dissolving the latter in dilute acid. Unfortunately the crystals had grown close together, thus interfering more or less with one another, and they also were cracked, probably owing to the severe shocks received in the processes of blasting and mining; consequently when liberated by dissolving the calcite they fell to pieces, so that usually only parts of crystals were available for measurement. The faces had a beautiful metallic luster, and when free from striations and vicinal planes gave excellent reflections on the goniometer. The determination of the crystalline form and the axial ratio proved to be a difficult matter owing to the fragmentary character of the crystals, their grouping, often in nearly parallel position, a probable twinning and their close approximation to rhombohedral symmetry, and it was not until many measurements had been made upon a series of crystals that a satisfactory solution of the problem was obtained.

As fundamental measurements, the following were selected:

$m \wedge m,\ 110 \wedge \bar{1}10 = 60^\circ\ 2'$
$c \wedge d,\ 001 \wedge 102 = 25\ \ 3$
$c \wedge a,\ 001 \wedge 100 = 89\ \ 51$

from which the axial ratio was calculated:

$$a : b : c = 1{\cdot}7309 : 1 : 1{\cdot}6199$$
$$\beta = 001 \wedge 100 = 89^\circ\ 51'.$$

The crystals are quite highly modified, and it seems best before giving a list of the forms to explain the different kinds which were observed and to state something concerning their occurrence. The basal pinacoid *c*, 001 is prominent, is hexagonal or triangular in shape, and is characterized by triangular markings and vicinal planes, fig. 1, so that it was often impossible to obtain accurate measurements from it. The prism *m*, 110 and the pinacoid *a*, 100 are nearly at right angles to *c* and 60° from one another, so that the combination approaches very closely to an hexagonal prism, and it is sometimes impossible to distinguish *a* from *m*, or without accurate measurements to decide whether the forms between *c* and *a* or *c* and *m* modify the acute or obtuse angles. It is very probable that a twinning is present, similar to that of the micas and chlorites, where the twinning plane is at right angles to *c* in the zone $m \wedge c$ and where the parts are superimposed upon one another with *c* as the composition face, but no absolute proof of this was obtained. The crystals are opaque, so that optical tests could not be applied as was done by Miers,* who has described this kind of twinning on polybasite. If the twinning occurs on pearceite, as it probably does, it must cause uncertainty as to the identification of some of the forms in the zones between *c* and *a* and *c* and *m*, and it may also account in part for the decidedly rhombohedral aspect of many of the crystals. As far as could be observed, similar faces are often developed about equally above and below *m* and *a* in the zones between the basal planes, but to what extent this is due to twinning it is impossible to state. The faces in these zones are moreover commonly striated parallel to their mutual intersection, and while *r* and *p*, r° and p°, *n* and *t* and n° and t° (compare fig. 1 and the list of forms beyond), are the most prominent, other faces, especially *e* and e°, *f* and f°, *s* and s° and *u* and u°, are very often present. When *q* was observed it was always a prominent, dull face, not sharing in the horizontal striations of the other faces of the zone. It was only occasionally that forms were observed between *c*, 001 and *l*, 310, and they were always small, while the corresponding forms were not observed between 001 and $\bar{3}10$. The pinacoid *b*, 010 was identified, not only by the symmetrical arrangement of the forms with reference to it, but also by the similarity of the angles measured

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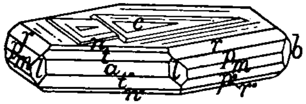
* Min. Mag., viii, p. 204, 1889.

from it on to similar adjacent forms. The prism *l*, 310 is often developed about equal in size to *b*, and with the latter would correspond in rhombohedral symmetry to a hexagonal prism of the second order. The prism *h*, 130 and the horizontal prism *k*, 021 were found together on only one crystal as small faces symmetrically located with reference to the pinacoid *b*.

1.



2.

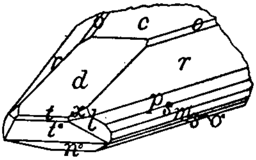


Fig. 1 shows the prevailing type of crystal, with hexagonal aspect, the characteristic triangular markings on the basal plane, but with only the most prominent of the bevelling faces present. Two fragments were found which in habit were essentially like fig. 2. These had a decidedly monoclinic habit and were the most free from striations, vicinal faces and indications of a possible twinning of any crystals that were observed, and from them the fundamental measurements previously given were obtained.

A few crystals were quite remarkable for their size, the hexagonal plates being 3^{cm} in diameter and 1^{cm} thick, but they were coated with druzy quartz and could not be used for crystallographic measurement. The specimen showing the largest crystals was presented by Mr. Bayliss to the author for the Brush collection at New Haven. The crystals from which the measurements were obtained averaged less than 4^{mm} in diameter.

The following list includes the forms which have been observed, but, as already stated, twinning may account for a similar form being found modifying both the acute and obtuse angles of the crystals and being repeated in the zones between *c* and *a* and *c* and *m*.

a, 100
b, 010
c, 001
l, 310
m, 110
h, 130
k, 021
d, 102
n, 101
t, 201
e, 401
f, 601
Δ, $\bar{2}03$
n°, $\bar{1}01$
t°, $\bar{2}01$
e°, $\bar{4}01$
f°, $\bar{6}01$
o, 114
r, 112
p, 111
v, 332
s, 221
u, 331
o°, $\bar{1}14$
q°, $\bar{1}13$
r°, $\bar{1}12$
p°, $\bar{1}11$
v°, $\bar{3}32$
s°, $\bar{2}21$
u°, $\bar{3}31$
x, 311
y, 313
z, 31·12

The forms corresponding to these found by Miers* on polybasite are *c*, *m*, *n*, *t*, *p*, *s*, *r* and *w*, 109.

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* Loc. cit.

The following table of measured angles includes a series which was selected wholly on account of the character of the reflections, due to the freedom of the faces from striations and other disturbing influences. They were mostly made on the two fragmentary crystals, already mentioned, having a habit like fig. 2, and where several measurements are given they represent independent ones in different zones or on different crystals. As may be seen, the measured angles show a fairly good agreement with the calculated values, and it may, therefore, be assumed that the axial ratio has been determined with a fair degree of accuracy.

		Calculated,	Measured.	
$c \wedge a$,	$001 \wedge 100$	89° 51′	89° 51′*,	89° 49′
$c \wedge l$,	$001 \wedge 310$	89 52	89 48,	89 54
$c \wedge m$,	$001 \wedge 110$	89 55½	89 55	
$m \wedge m$,	$110 \wedge \bar{1}10$	60 2	60 2*	
$b \wedge m$,	$010 \wedge 110$	30 1	30 1,	30 1
$a \wedge l$,	$100 \wedge 310$	29 59	29 58,	29 57¼
$b \wedge h$,	$010 \wedge 130$	10 54	10 53	
$b \wedge k$,	$010 \wedge 021$	17 9	17 5	
$c \wedge d$,	$001 \wedge 102$	25 3	25 3*,	25 2½
$c \wedge n$,	$001 \wedge 101$	43 2	43 4,	43 5
$c \wedge e^\circ$,	$001 \wedge 40\bar{1}$	104 49	104 53½	
$c \wedge t^\circ$,	$001 \wedge 20\bar{1}$	118 00	117 56	
$c \wedge n^\circ$,	$001 \wedge 10\bar{1}$	136 49½	136 52½	
$c \wedge r$,	$001 \wedge 112$	43 3	43 3,	43 6 43 0
$c \wedge p$,	$001 \wedge 111$	61 49	61 56	
$d \wedge r$,	$102 \wedge 112$	36 14	36 12,	36 16
$b \wedge p$,	$010 \wedge 111$	40 15	40 12,	40 12
$b \wedge p^\circ$,	$010 \wedge \bar{1}11$	40 10½	40 8	
$b \wedge s$,	$010 \wedge 221$	33 12	33 12	
$c \wedge y$,	$001 \wedge 313$	47 9	47 10,	47 7

In the following table the calculated angles of most of the faces on to the basal plane are given, arranged so as to show the slight variation from one another and from rhombohedral symmetry of the forms *d*, *o* and *o*° ; *Δ* and *q*° ; *n*, *r*, *n*° and *r*° ; *t*, *p*, *t*° and *p*° ; *v* and *v*° ; *e*, *s*, *e*° and *s*° and *f*, *u*, *f*° and *u*°.

$c \wedge d$ = 25° 3′
$c \wedge o$ = 25 3
$c \wedge o^\circ$ = 25 4½
$c \wedge \Delta$ = 32 0
$c \wedge q^\circ$ = 31 58
$c \wedge n$ = 43 2
$c \wedge r$ = 43 3

$c \wedge n^\circ$ = 43° 10½′
$c \wedge r^\circ$ = 43 7½
$c \wedge t$ = 61 46½
$c \wedge p$ = 61 49
$c \wedge t^\circ$ = 62 00
$c \wedge p^\circ$ = 61 56

$c \wedge v$ = 70° 19′
$c \wedge v^\circ$ = 70 27
$c \wedge e$ = 74 54
$c \wedge s$ = 75 00
$c \wedge e^\circ$ = 75 11
$c \wedge s^\circ$ = 75 6

$c \wedge f$ = 79° 45′
$c \wedge u$ = 79 49½
$c \wedge f^\circ$ = 80 2
$c \wedge u^\circ$ = 79 58
$c \wedge z$ = 15 6½
$c \wedge y$ = 47 9
$c \wedge x$ = 72 44

Physical properties.—Pearceite is brittle, has an irregular to conchoidal fracture and no distinct cleavage. The hardness is about 3. The specific gravity was taken with a chemical balance on three different portions of carefully selected material and gave 6·125, 6·160 and 6·166, the mean of these being 6·15. The luster is metallic and the color of the mineral and the streak is black. The material, even in thin particles, is opaque. In the ruby silvers the arsenical compound proustite is more transparent than the antimony one pyrargyrite, and we might, therefore, naturally expect pearceite to be more transparent than polybasite, but that this is not the case may be due to the fact that the variety of pearceite under examination contains over 18 per cent of copper, while the published analyses of polybasite indicate usually about 5 and never over 10 per cent of this element.

Pyrognostics and other tests.—Before the blowpipe, pearceite decrepitates slightly and fuses at about one. Heated on charcoal in the oxidizing flame, a slight coating of As_2O_3 is formed and by addition of borax or sodium carbonate and continued heating a globule of metallic silver is obtained. In the open tube SO_2 is given off and a volatile sublimate of As_2O_3 is formed. In the closed tube the mineral fuses, yields a yellow sublimate of sulphide of arsenic and above the latter a very slight one of sulphur. The powder is readily oxidized and dissolved by nitric acid, the solution yields with hydrochloric acid an abundant precipitate of silver chloride and on addition of ammonia in excess the blue color characteristic of copper is obtained, while a slight precipitate of ferric hydroxide is formed.

Occurrence.—According to information received from Mr. Bayliss, the pearceite crystals were found with quartz and calcite lining a vug at only one place in the Drumlummon mine, and although a diligent search has been made for similar crystals in other parts of the mine none have been found. A few chalcopyrite crystals were observed intimately associated with the pearceite. High grade silver and gold ores are taken from the Drumlummon mine, and on one of the specimens of the ore argentiferous tetrahedrite, freibergite, was observed.

2. *The Crystallization of Polybasite.*

Rose originally described polybasite as rhombohedral and it was thus considered until 1867, when Des Cloizeaux* observed that the transparent plates showed in convergent polarized light a biaxial and not a uniaxial interference figure and that the mineral, therefore, could not be rhombohedral. The crystals were then referred to the orthorhombic system, but the close approximation to rhombohedral symmetry has always

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* Nouvelles Recherches, p. 85, 1867.

been prominently noted in descriptions of the mineral. The earlier measurements of polybasite crystals by Breithaupt* are untrustworthy, probably owing to the difficulty of securing suitable material, and we are indebted to Miers† for the first careful series of measurements, which were made upon a suite of crystals in the British Museum. He also evidently experienced some difficulty in obtaining reliable measurements, for the angles between similar faces show a considerable variation amounting usually from a quarter to one-half of a degree. The crystals are regarded by him as orthorhombic and the following forms were observed :

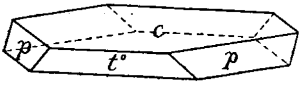
c, 001	*w*, 109	*t*, 201	*p*, 111
m, 110	*n*, 101	*r*, 112	*s*, 221

Prominent angles are $m : m$, $110 \wedge \bar{1}10 = 60° \; 10'$; $c \wedge n$, $001 \wedge 101 = 42° \; 24'$ and $c \wedge p$, $001 \wedge 111 = 61° \; 14'$, the axial ratio being $a : b : c = 1{\cdot}7262 : 1 : 1{\cdot}634$. He also observed that the crystals when examined in polarized light did not become dark in any position and concluded, therefore, that they were twinned, as already explained on page 20 for pearceite. He points out the impossibility of distinguishing the bevelling faces *r* and *p* in the zone between *c* and *m* from *n* and *t* in the zone between *c* and *a*, and calls attention to the fact that the only form in these zones at right angles to the base is the prism *m* and that the pinacoid *a*, 100 fails. When six faces occur in the zone of the prisms the ones which occupy the positions of the pinacoid *a* are the prismatic faces *m* in twin position.

Dana‡ accepts the measurements of Miers as fundamental but shifts the position of the crystal so that the obtuse angle of the prism, $m \wedge m$, is in front.

Among the specimens in the Brush collection at New Haven one was found from the Himmelfahrt mine, Freiberg in Saxony, showing crystals like fig. 3, which is *apparently* a combination of base and rhombohedron. On revolving the crystals in polarized light they never became dark, showing thus that

3.



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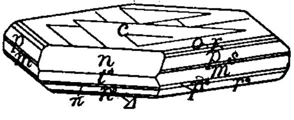

a twinning was present, while in convergent light a confused interference figure was usually obtained, although in places the

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* Charakteristik des Mineral-Systems, 1832, p. 266.

† Min. Mag., viii, p. 204, 1889.

‡ System of Mineralogy, 6th edition, p. 146.

normal biaxial one was seen. There is nothing in the external aspect of the crystal to indicate twinning except perhaps the uneven character of the base *c*, which may result from a twinning about *m*, 110 and a slight deviation from 90° of $c \wedge m$. The crystal did not give satisfactory reflections, but the angle of *c* on the apparent rhombohedrons was approximately 61½° and of the latter faces on to each other 80½°. It is difficult to explain this apparently rhombohedral development on the assumption that the crystallization is orthorhombic, while it is known that monoclinic minerals whose prismatic angles are near 60°, the micas, chlorites and leadhillite for example, exhibit in a marked degree a tendency to imitate rhombohedral symmetry, while orthorhombic compounds, chalcocite, aragonite and witherite for example, do not show this tendency. It seems reasonable, therefore, to assume that the crystallization of polybasite, like that of pearceite, is *monoclinic*, and the apparently rhombohedral forms on fig. 3 have accordingly been lettered *p* and *t*° with the understanding that there is an uncertainty regarding their identification.

In the summer of 1891, while the author was engaged in some mineralogical work in Colorado for the United States Geological Survey, a collection of minerals was made at the Yankee Boy mine, near Ouray, and thanks are due to Dr. F. M. Endlich, manager of the mine, for his courtesy and the interest which he took in making the collection as complete as possible. On the specimens, associated with pyrargyrite and implanted upon quartz, were some small but remarkably perfect crystals of polybasite. The occurrence of the mineral from this locality has been noted by Endlich,* the identification being based in part upon measurements by the author of the prismatic angle $m \wedge m$ = nearly 60°.

The forms which were observed on a single crystal of polybasite, having a habit like fig. 4, are as follows, the orientation being derived from the symmetrical arrangement of the faces with reference to the prism *l*, 310, which, however, was only slightly developed and is not represented in the figure.

c,	001	*Δ*,	$\bar{2}03$	*o*,	114	*u*,	331 ?
l,	310	*n*°,	$\bar{1}01$	*r*,	112	*o*°,	$\bar{1}14$
m,	110	*π*,	$\bar{4}03$	*p*,	111	*r*°,	$\bar{1}12$
n,	101	*t*°,	$\bar{2}01$	*s*,	221	*p*°,	$\bar{1}11$

The crystal was too opaque to admit of optical tests being made, but thinner crystals from the locality transmitted a deep red light and showed indications of twinning.

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* This Journal, xl, p. 424, 1890.

The following angles were taken as fundamental:

$c \wedge m$, $001 \wedge 110 = 90° \; 0'$
$m \wedge m$, $110 \wedge \bar{1}10 = 60 \;\; 2$
$c \wedge n$, $001 \wedge 101 = 42 \;\; 23$

from which the axial ratio was calculated

$$a : b : c = 1{\cdot}7309 : 1 : 1{\cdot}5796$$
$$\beta = 90° \; 0'$$

The following table gives a record of the measurements which were made mostly on one crystal. The ones in brackets represent approximate measurements from very narrow faces.

	Calculated.	Measured.		Limits obtained by Miers.
$c \wedge m$, $001 \wedge 110$	90° 0′	90° 0′*	90° 4	
$c \wedge l$, $001 \wedge 310$	90 0	90 0	90 2′	
$m \wedge m$, $110 \wedge \bar{1}10$	60 2	60 2*	60 0	60° 10′–
$c \wedge n$, $001 \wedge 101$	42 23	42 23*	42 23	40 48–42° 30′
$c \wedge \Delta$, $001 \wedge \bar{2}03$	31 19	31 22		
$c \wedge n°$, $001 \wedge \bar{1}01$	42 23	42 23		
$c \wedge \pi$, $001 \wedge \bar{4}03$	50 35	50 44		
$c \wedge t°$, $001 \wedge \bar{2}01$	61 17	61 25		61 8–61 17
$c \wedge o$, $001 \wedge 114$	24 31	(24 43)		
$c \wedge r$, $001 \wedge 112$	42 22	(42 43)	(42 9)	40 48–42 30
$c \wedge p$, $001 \wedge 111$	61 16	61 15	(61 7)	61 5–61 24
$c \wedge s$, $001 \wedge 221$	74 40	(74 48)		73 55–75 50
$c \wedge u$, $001 \wedge 331$	79 39	(78 2) ?		
$c \wedge o°$, $001 \wedge \bar{1}14$	24 31	(24 36)		
$c \wedge r°$, $001 \wedge \bar{1}12$	42 22	42 24		
$c \wedge p°$, $001 \wedge \bar{1}11$	61 16	(60 35)		
$l \wedge p$, $310 \wedge 111$	40 35½	40 36		
$p \wedge r°$, $111 \wedge \bar{1}12$	49 26	49 27		
$r° \wedge t°$, $\bar{1}12 \wedge \bar{2}01$	49 24½	49 38		
$t° \wedge l$, $\bar{2}01 \wedge \bar{3}\bar{1}0$	40 34	40 34		

Certainly, as shown by the above table, the agreement between the measured and calculated values is very satisfactory, and it may be assumed, therefore, that the axial ratio has been determined with a fair degree of accuracy. That the crystallization is really monoclinic is shown by the development and arrangement of the faces, but the angle β differs so little from 90° that the variation, if any, falls within the errors of observation. Of four measurements that were made of $c \wedge l$, the faces being free from striations and giving excellent reflections, two were 90° 0′ and the others 90° 2′. Six independent measurements of $c \wedge m$ were made varying between 90° 0′ and 90° 6′, but the m faces were slightly striated so that the measurements are not quite so reliable as those of $c \wedge l$.

Relations of pearceite and polybasite to each other and to other minerals.—Pearceite and polybasite show, as would be expected, a very close relation to one another in everything which concerns their crystallization. The tendency of arsenic is to make the vertical axis of its compound a little longer than that of the antimony one, as shown by the following ratios and by the angles $c \wedge p$ or p°:

	a : b : c	β	$c \wedge p$ and p°.	
Pearceite,	1·7309 : 1 : 1·6199	89° 51′	61° 49′	61° 56′
Polybasite,	1·7309 : 1 : 1·5796	90° 0′	61 16	

Perhaps the next most interesting relation of these minerals, which imitate rhombohedral symmetry, is their very close similarity to the rhombohedral ruby silvers, proustite $Ag_3A_sS_3$ and pyrargyrite Ag_3SbS_3, as shown by the relations of the vertical axis and the angles.

		$c \wedge p$ or p°			$c \wedge s$
Pearceite,	$\frac{1}{2} c = 0·8099$	61° 49′–61° 56′	Proustite,	$c = 0·8039$	61° 41½′
Polybasite,	$\frac{1}{2} c = 0·7898$	61 16 –	Pyrargyrite,	$c = 0·7891$	61 15
Difference =	·0201		Difference =	·0148	

The vertical axes are longer in the arsenic than in the antimony compounds and to about the same extent in the two classes. In proustite and pyrargyrite *s* is the −2 rhombohedron, $02\bar{2}1$.

The orthorhombic sulphides, chalcocite Cu_2S and stromeyerite CuAgS, also exhibit a close and striking similarity to the minerals in question, best seen when the positions of the former are changed by a simple interchange of the *a* and *b* axes, making thus the obtuse angles of the prisms at the extremities of the *b* instead of the *a* axis, as follows:

	a : b : c	β	$m \wedge m$, $110 \wedge \bar{1}10$	$c \wedge p$ or p°
Chalcocite,	1·7176 : 1 : 1·6663	90° 0′	60° 25′	62° 35½′
Stromeyerite,	1·7176 : 1 : 1·6603	90 0	60 25	62 30
Pearceite,	1·7309 : 1 : 1·6199	89 51	60 2	61 49–61° 56′
Polybasite,	1·7309 : 1 : 1·5796	90 0	60 2	61 16

Although widely separated in our chemical classification, the differences in chemical composition of the two former from the two latter is not so very great, for Cu and Ag being isomorphous we have as the general composition of the former R'_2S and of the latter $R'_2S+\frac{1}{9}As_2S_3$ respectively Sb_2S_3.

On examining the whole group of sulpharsenites and sulphantimonites it is quite interesting to note that the majority of them which are well crystallized exhibit prismatic angles of nearly 60° and show forms in other zones which can be referred to vertical axes nearly like those of the chalcocite and polybasite groups. These relations are shown in the following table, where the compounds are arranged according to variations in basisity. The axes and angles have been taken from the sixth edition of Dana's Mineralogy, with the exception of those of xanthoconite and pyrostilpnite, which are taken from Miers,* and of jordanite, taken from Baumhauer.**

Name.	Composition.	Syst.	$a : b : c$	β	$m \wedge m'$	$c \wedge p$ or equivalent.	Change of axes from Dana's position.
Chalcocite	Cu_2S	O	1·718 : 1 : 1·666		60° 25′	62° 35′	$a=b$
Pearceite	$9Ag_2S . As_2S_3$	M	1·731 : 1 : 1·620	89° 51′	60 2	61 49	
Polybasite	$9Ag_2S . Sb_2S_3$	M	1·731 : 1 : 1·580	90 00	60 2	61 16	
Stephanite	$5Ag_2S . Sb_2S_3$	O	1·589 : 1 : 1·633		64 21	62 37	$a=b . \frac{3}{2}c$
Geocronite	$5PbS . Sb_2S_3$	O	1·723 : 1 : 1·732		60 16		$a=b . 2c$
Jordanite	$4PbS . As_2S_3$	M	1·862 : 1 : 1·883	90 33†	56 30	65 01	$b=c . \frac{1}{2}c$
Meneghinite	$4PbS . Sb_2S_3$	O	1·891 : 1 : 1·831		55 45		$a=b . 2\frac{2}{3}c$
Proustite	$3Ag_2S . As_2S_3$	R	1·732 : 1 : 1·608		60 0	61 41½	$2c$
Pyrargyrite	$3Ag_2S . Sb_2S_3$	R	1·732 : 1 : 1·578		60 0	61 15	$2c$
Xanthoconite	$3Ag_2S . As_2S_3$	M	1·919 : 1 : 1·523	88 47	55 4		$\frac{3}{2}c$
Pyrostilpnite	$3Ag_2S . Sb_2S_3$	M	1·946 : 1 : 1·646	90 00	53 21		$\frac{3}{2}c$
Bournonite	$3(Pb, Cu_2)S . Sb_2S_3$	O	1·875 : 1 : 1·793	$f \wedge f=$	56 8	63 48	$2a .$ $2c$
Freieslebenite	$5(Pb, Ag_2)S . 2Sb_2S_3$	M	1·703 : 1 : 1·580	92°14†	60 48		$a=b .$
Dufrenoysite	$2PbS . As_2S_3$	O	1·531 : 1 : 1·876	$i \wedge i=$	66 18		$a=c . 2c$
Jamesonite	$2PbS . Sb_2S_3$	O	? : 1 : 1·830				$a=c . 2c$
Sartorite	PbS, As_2S_3	O	1·856 : 1 : 1·722		56 38		$a=b . \frac{3}{2}c$
Zinkenite	$PbS . Sb_2S_3$	O	1·794 : 1 : 1·709		58 17		$a=b . \frac{3}{2}c$

M = Monoclinic. O = orthorhombic. R = rhombohedral.

In the majority of cases in the above table the change from the position given in Dana has been made by a simple interchange of the a and b axes and by multiplying the vertical axis in its new relation by a simple factor. The isomorphous relations of jordanite and meneghinite, studied by Miers,‡ Krenner,§ Schmidt‖ and Groth¶ are not at all clear. The factor $2\frac{2}{3}$ given for the vertical axis is a rather unnatural one, which if adopted would give to the forms observed on meneghinite very complicated indices. The axial ratio suggested by Schmidt, $a : b : c = 0·4862 : 1 : 1·8465$, would give by interchange of a and b and using the factor $\frac{1}{2}$ for the vertical axis $a : b : c = 2·0568 : 1 : 1·8984$ and $m \wedge m = 51° 52'$, values which show the widest variations of any in the table from polybasite. It will be noticed that the vertical axes of the arsenical

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* Min. Mag., x, p. 185, 1893.

** Sitz. Ber. Akad. d. Wiss., Berlin, 1891, p. 697.

† Owing to the change of position of the axes, the inclination for jordanite becomes γ instead of β and for freieslebenite a instead of β.

‡ Min. Mag., v, p. 325, 1884.

§ Földt. Közl., xiii, p. 297, 1883.

‖ Zeitschr. Kryst., viii, p 613, 1883.

¶ Tabellarische Uebersicht, p. 33, 1889.

compounds pearceite, jordanite, proustite, dufrenoysite and sartorite are greater than those of the corresponding antimony compounds, while xanthoconite and pyrostilpnite form an exception to this rule, which may, however, be due to inaccuracy in the measurement of the small crystals of these exceedingly rare minerals. The relations shown in the table may be accidental, but the close approximation of the axial ratios to that of chalcocite would seem to indicate that the sulphide of the metal has had a controlling influence on the crystallization. Sternbergite, $Ag_2S.Fe_4S_5$ with $m \wedge m = 60° 30'$ and enargite, $3Cu_2S.As_2S_5$ with $x \wedge x'''$, $320 \wedge 3\bar{2}0$ (twinning plane) $= 60° 17'$ might be added to the table.

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ART. V.—*The Hydrology of the Mississippi;* by JAMES L. GREENLEAF, C.E.

A RIVER of the size of the Mississippi necessarily has many and important tributaries, with their individual peculiarities of watershed, channel, and variation in flow. Each of these tributaries exerts its proportionate influence upon the stream which is the resultant, and a knowledge of them is therefore essential to a study of the hydrology of the main river. For this reason, sixteen of the branches especially influential in forming the character of the Mississippi, have been selected for a brief discussion.

As a preliminary, it will be well to consider for a moment the point of view from which the engineering profession examines the hydrology of a watershed. Whatever the purpose that the engineer has in working upon a river, be it water power, water supply of towns, irrigation, the training of the current to prevent devastating overflows or to maintain a depth for navigation; in each and all of these problems two fundamental considerations force themselves upon his attention. They are the degree of regularity, and the amount of the volume of flow from the tributary country. Thus, in the south, the Mississippi River Commission and the Levee Boards find the flow volume a vital feature in their efforts to confine the stream in a definite channel. At the north, the Engineer Corps of the United States Army are constructing a system of reservoirs for holding back the freshets and aiding navigation upon the upper river during the season of low flow.