

ART. IV.—*On the Identity of Chalcostibite (Wolfsbergite) and Guejarite, and on Chalcostibite from Huanchaca, Bolivia*; by S. L. PENFIELD and A. FRENZEL.

Introduction.—In December, 1894, Mr. Thomas Hohmann, mining engineer at Valparaiso, Chili, sent to one of us (Frenzel), for examination, some specimens, from the Pulacayo mine, Huanchaca, Bolivia. Upon one of these were some prismatic crystals of a mineral with metallic luster, which, we were informed by Mr. Hohmann, was found very sparingly, was unknown to him, and might possibly be new or worthy of investigation. As the material was limited, it was decided to identify the mineral, if possible, by its crystalline form, and, upon examination, it was found that the cleavage and some of the prominent crystal forms corresponded to the rare mineral guejarite, described by Cumenge* as having the composition $Cu_2S \cdot 2Sb_2S_3$.

About the same time that this material was sent to us, a second specimen from Huanchaca was received at the *Mineralien Niederlage* at Freiberg, Saxony, and Herr Zinkeisen, director of that institution, on learning that the mineral had been identified as guejarite, sent the specimen to Mr. L. Fletcher of London, and it was purchased for the mineral collection of the British Museum. In order to identify this mineral with certainty, Mr. Fletcher requested Mr. L. J. Spencer, of the Mineral Department of the British Museum, to examine the crystals, when it was found that the forms agreed not only with guejarite, but equally well with chalcostibite (wolfsbergite). An article was accordingly prepared by Mr. Spencer "On Wolfsbergite from Bolivia; and the probable identity of Wolfsbergite and Guejarite,"† but on learning that we were engaged in an investigation of the same mineral, Mr. Fletcher called our attention to the fact that guejarite could not be distinguished crystallographically from chalcostibite. He also requested Mr. Spencer to send the results of his investigation to us, in order that his results might be incorporated with ours, and in subsequent pages it will be shown that guejarite, which has been considered as having the composition $Cu_2S \cdot 2Sb_2S_3$, is really identical with chalcostibite (wolfsbergite), $Cu_2S \cdot Sb_2S_3$.

Chalcostibite from Wolfsberg in the Harz.—Upon material from this locality, the species was first founded in 1835, by Zinken,‡ the mineral being called by him *Kupferantimonglanz*.

* Bull. Soc. Min. de France, ii, p. 201, 1879.

† Read before the Mineralogical Society of London, April 14, 1896.

‡ Pogg. Ann., xxxv, p. 357, 1835.

The composition $\text{Cu}_2\text{S} \cdot \text{Sb}_2\text{S}_3$ was established by an analysis by H. Rose,* and the crystals were measured and determined to be orthorhombic by G. Rose,† who identified two prisms and a pinacoid in one zone, but as no terminal faces were observed, the axial ratio could not be fully determined. The name *rosite* was assigned to the species in 1841, by Huot,‡ but on account of its similarity to *roselite*, it has not been generally accepted. In 1847 the mineral was called *chalcostibite* by Glocker,§ and in 1849 *wolfsbergite*, by Nicol.|| Glocker's name thus antedates Nicol's, and there seems to be no reason for not accepting it, although wolfsbergite is in common use.

Terminated crystals of chalcostibite from Wolfsberg are very rare, and we are indebted to Laspeyres¶ for the only description of them, and for the determination of the axial ratio. In order to show a crystallographic relation between chalcostibite and the similarly constituted minerals zinkenite, $\text{PbS} \cdot \text{Sb}_2\text{S}_3$; sartorite, $\text{PbS} \cdot \text{As}_2\text{S}_3$ and emplectite, $\text{Cu}_2\text{S} \cdot \text{Bi}_2\text{S}_3$, the crystals were orientated so as to make the perfect cleavage basal, and the prominent prismatic development parallel to the crystallographic axis *b*.

The forms that were identified by Laspeyres are as follows:

<i>c</i> , 001	<i>d</i> , 101	<i>f</i> , 011	<i>p</i> , 7·14·8**
<i>e</i> , 307	<i>g</i> , 201	<i>q</i> , 863	<i>r</i> , 7·21·27**

The axial ratio was derived from measurements of the pyramid *p*, and was found by Laspeyres to be $a:b:c = 0.5283:1:0.6234$, but by giving to *p* the indices 6·12·7 instead of 7·14·8, the axial ratio becomes $0.5283:1:0.6364$. Some of the important measurements made by Laspeyres will be found in column I, in the tables on page 34, et seq.

Chalcostibite (guejarite) from Guejar in Spain.—The identity of guejarite as a distinct mineral species had been based upon the following analysis by Cumenge: ††

	Found.	Theory for $\text{Cu}_2\text{S} \cdot 2\text{Sb}_2\text{S}_3$.
S	25·0	27·0
Sb	58·5	57·8
Cu	15·5	15·2
Fe	0·5	----
Pb	tr.	----
	99·5	100·0

* Ibid, p. 361.

† Mineralogy, i, p. 197.

‡ Mineralogy, p. 484.

† Ibid, p. 360.

§ Syn., p. 32.

¶ Zeitschr. Kryst., xix, p. 428, 1891.

** As will be shown later, 7·14·8 and 7·21·27 should be 6·12·7 and 134, respectively.

†† Loc. cit.

Although the results agree fairly well with the theoretical composition, an analysis in which the determinations are carried out only to half per cents cannot be considered wholly satisfactory for the establishment of a mineral species, and, as neither the method of analysis is given nor any statement concerning the amount of material taken, the results cannot be fairly criticised. As crystals of chalcostibite resemble those of stibnite in color, luster, habit, and cleavage, and, further, as stibnite would probably occur at a locality where chalcostibite is found, as is the case at Wolfsberg in the Harz, it is possible that the material analyzed by Cumenge contained some stibnite, which would account for his failure to obtain the correct formula. It may be noted here that Rammelsberg, in the second supplement of his *Handbuch der Mineralchemie*, p. 54, 1895, places an interrogation after the formula of guejarite.

The crystallization of the mineral was determined as orthorhombic by C. Friedel.* The habit is prismatic, with the faces in the prominent zone striated and grading into one another, owing to oscillatory combinations of a series of prisms. Crystals showing terminations are rare. In the position adopted by Friedel, the nearly perfect cleavage in the prismatic zone was taken as b , 010, and the following forms were identified:

b , 010	h , 210	m , 110	d , 013
c , 001	k , 320†	l , 230†	e , 011

In addition to the foregoing, the doubtful forms 410, 310, and 032 are mentioned and likewise two pyramids, x ($b \wedge x = 56^\circ 24'$), and z ($b \wedge z = 39^\circ 58'$), but the symbols of these latter forms cannot be determined, as only a single measurement is given for each. The axial ratio obtained by Friedel is $a : b : c = 0.8221 : 1 : 0.7841$.

In order to bring the crystals into the position adopted by Laspeyres for chalcostibite, it is necessary to change the orientation so that the nearly perfect cleavage is basal, c , 001, and the prominent prismatic zone parallel to the crystallographic axis b . Twice the length of Friedel's vertical axis is taken as the unit length of b , and the axial ratio thus becomes $a : b : c = 0.5242 : 1 : 0.6377$, while that derived from Laspeyres' measurements is $a : b : c = 0.5283 : 1 : 0.6364$.

In the following table, the forms observed by Friedel are given, together with the indices when transposed to the position adopted by Laspeyres:

* Bull. Soc. Min. de France, ii, p. 203, 1879.

† The forms 320 and 230 are given by Friedel as 730 and 370, respectively.

Guejarite. Position.		Chalcostibite. Position.		Guejarite. Position.		Chalcostibite. Position.
<i>b</i> , 010	=	<i>c</i> , 001		<i>m</i> , 110	=	<i>d</i> , 101
<i>c</i> , 001	=	<i>b</i> , 010		<i>l</i> , 230	=	<i>h</i> , 203
<i>h</i> , 210	=	<i>g</i> , 201		<i>d</i> , 013	=	<i>u</i> , 061
<i>k</i> , 320	=	<i>i</i> , 302		<i>e</i> , 011	=	<i>t</i> , 021

At the conclusion of his article, Friedel calls attention to the close similarity in the angle of his prism, $m \wedge m = 101^\circ 9'$, with that of the chalcostibite prism $101^\circ 0'$ measured by Rose.

In the Brush collection at New Haven, there is a specimen of chalcostibite from Guejar, which was presented by Professor Groth of Munich. It is a fragment of a crystal, without terminal planes, and in appearance it agrees exactly with the description of guejarite given by Friedel. However, in order to make sure of its identity with the material described by him, it was carefully measured, with the results which will be found in column IV in the table on page 34. The specimen weighed a little over one gram, and the specific gravity was found to be 4.959. Cumenge gives 5.03.

Professor Groth very kindly responded to a request to supply us with some of this rare material for a chemical analysis, and he also furnished measurements of a crystal with terminal planes, belonging to the Munich collection. These measurements were made by Mr. Schott, and are given in column V on page 34. The habit of this crystal is shown in fig. 1.



Requests for material were also sent to Professor Friedel and Mr. Cumenge, and they were able to supply us with some of the original mineral from Guejar investigated by them. That received from Professor Friedel was a small fragment of a crystal, weighing 0.108 gram, which corresponded in every particular with that given to us by Professor Groth. Before using it for analysis, however, it was carefully measured, with the results which are given in column III on page 34. The material supplied by Mr. Cumenge consisted of small, finely striated crystal fragments which were not adapted for measurement. They weighed 0.428 gram, and, before subjecting them to analysis, each crystal was tested for copper so as to make sure that there were no stibnite crystals amongst them.

The results of the analyses (by Frenzel) of the specimens received from Professors Groth and Friedel, and Mr. Cumenge, are given below in the columns I, II and III respectively.

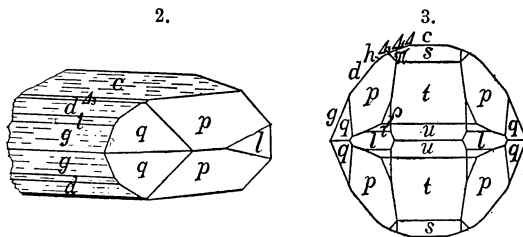
Specific gravity 4.96.			Ratio.		II.	III.	Theory for Cu ₂ S. Sb ₂ S ₃ .
I.							
S.	26.28 ÷ 32 =		.821	4.00	S	26.12	25.87
Sb	48.86 ÷ 120 =		.407	1.995	Sb	48.50	48.50
Cu	24.44 ÷ 126.8 = .193	} .202	0.995		Cu	25.92	25.63
Pb	.58 ÷ 207 = .002				Pb	.32	----
Fe	.42 ÷ 56 = .007				Fe	.49	----
					Zn	.18	----
<hr/>						<hr/>	<hr/>
100.58						100.78	100.00

In the first analysis the ratio of S:Sb:(Cu₂+Pb+Fe) is almost exactly 4:2:1, which is that demanded by the chalcostibite formula Cu₂S.Sb₂S₃. The results of the second and third analyses are almost identical with those of the first, so we are thus enabled to establish beyond all doubt the identity in chemical composition of guejarite with chalcostibite.

Chalcostibite from Huanchaca, Bolivia.—On the specimen sent to us by Mr. Hohmann, the chalcostibite occurred as prismatic crystals averaging about 1^{mm} in diameter and 2^{mm} in length, which were attached to a gangue of quartz and pyrite vein material. Some massive tetrahedrite was also present, but the chalcostibite crystals were not found directly upon it. Although the crystals were isolated and quite numerous, only a few were implanted so that they could be removed and used for measurement. Doubly terminated ones were not observed. The crystals are quite highly modified, and the forms that have been identified are given in the following table, where those which are new are indicated by an asterisk:

<i>c</i> , 001	<i>h</i> , 203*	<i>t</i> , 021	<i>ν</i> , 133*
<i>l</i> , 130*	<i>d</i> , 101	<i>u</i> , 061	<i>π</i> , 265*
<i>Δ</i> , 209*	<i>i</i> , 302*	<i>q</i> , 863	<i>ρ</i> , 263*
<i>Δ</i> ₁ , 207*	<i>g</i> , 201	<i>p</i> , 6.12.7	<i>σ</i> , 4.12.5*
<i>Δ</i> ₃ , 205*	<i>s</i> , 065*	<i>μ</i> , 136*	<i>τ</i> , 261*

The large development of the pyramids *p* and *q*, whose indices are complicated, corresponds almost exactly with the description given by Laspeyres of the occurrence of the same found on the crystals from Wolfsberg. These pyramids were free from striations and vicinal developments, and gave excellent reflections. A few crystals were observed which have the habit represented in fig. 3, by a projection upon the pinacoid 010. All the pyramidal forms given in the foregoing table were observed upon a single crystal of this habit, but, of the faces in the zone between *c* and *l*, all of which were quite small, *μ*, *ν* and *σ* are not represented in the figure.



The axial ratio given below was derived from exceptionally good measurements of the pyramid *g*, 863.

$$863 \wedge \bar{8}63 = 126^\circ 21'$$

$$863 \wedge 86\bar{3} = 138^\circ 21'$$

$$a : b : c = 0.5312 : 1 : 0.63955$$

Laspeyres' measurements yield 0.5283 : 1 : 0.6364

Friedel's measurements yield 0.5242 : 1 : 0.6377

A list of the measured angles will be found in column VI in the tables on page 34, et seq.

Although the amount of material was limited, by careful selection a sufficient quantity of the pure, crystallized mineral was obtained for a chemical analysis, which was made by Frenzel, and gave the following results, corresponding with the theory demanded by the chalcostibite formula :

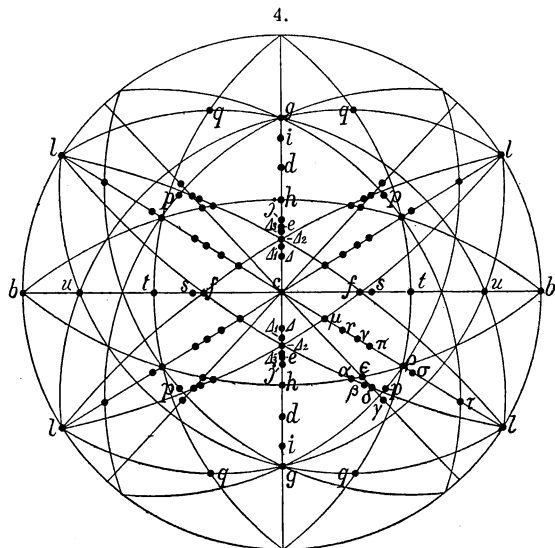
	Found.	Theory for $\text{Cu}_2\text{S} \cdot \text{Sb}_2\text{S}_3$.
S	26.20	25.87
Sb	48.45	48.50
Cu	24.72	25.63
	99.37	100.00

Mr. L. J. Spencer gives the following description of the chalcostibite specimen from Huanchaca, belonging to the British Museum. The small, bright, blade-shaped crystals of chalcostibite occur upon a specimen consisting mostly of massive and crystallized quartz, pyrite and tetrahedrite. The chalcostibite crystals are flattened parallel to the pinacoid *c*, 001, and are elongated and striated parallel to the crystallographic axis *b*. They are sometimes terminated at the ends by unsymmetrically developed, narrow, pyramidal planes, but more often by dull rounding surfaces approximating in position to the pinacoid 010. The forms that were observed are given in the table below, those which are new being indicated by an asterisk :

<i>η</i> , 205	<i>g</i> , 201	<i>γ</i> , 474*
<i>i</i> , 302	<i>a</i> , 233*	<i>δ</i> , 475*
<i>d</i> , 101	<i>β</i> , 354*	<i>ε</i> , 476*

The measurements obtained by him will be found in column VII in the tables on page 35.

Summary of the crystallographic investigations.—The following table includes all the forms which have been identified



on chalcostibite, and their distribution is shown by the spherical projection, fig. 4 :

b , 010	Δ_s , 205	f , 011	μ , 136	τ , 261
c , 001	e , 307	s , 065	r , 134	α , 233
l , 130	j , 102	t , 021	ν , 133	β , 354
Δ , 209	h , 203	u , 061	π , 265	γ , 474
Δ_1 , 207	d , 101	q , 863	ρ , 263	δ , 475
Δ_s , 103	i , 302	p , 6.12.7	σ , 4.12.5	ϵ , 476
	g , 201			

All investigators call attention to the striated character of the crystals in the direction of the crystallographic axis b , and, owing to the difficulty of always obtaining reliable measurements, there may be uncertainty in the identification of some of the forms in the zone $100:001$. The only forms which have been identified as prominent ones in this zone are h , d , and g . The prominent development of the pyramids p and q with such complicated indices as 6.12.7 and 863, respectively, on crystals from both Wolfsberg and Huanchaca, is certainly very unusual, and there seems to be nothing gained by giving to one of these forms simpler indices, since that would add very much to the complexity of the remaining forms.

In addition to the perfect basal cleavage, traces of cleavages parallel to the pinacoids 100 and 010 were observed.

In the succeeding tables, the calculated values are derived from the axial ratio $a:b:c = 0.5312:1:0.63955$, and the measurements made by various investigators are indicated by Roman numerals placed above the columns, as follows:

- I. Laspeyres. Crystals from Wolfsberg in the Harz.
- II. Friedel. Crystals from Guejar in Andalusia.
- III. Penfield. Fragment of crystal from Guejar, received from Prof. Friedel.
- IV. Penfield. Fragment of crystal from Guejar, received from Prof. Groth.
- V. Schott. Terminated crystal from Guejar, belonging to the Munich collection.
- VI. Penfield. Crystals from Huanchaca, Bolivia.
- VII. Spencer. Crystals from Huanchaca, Bolivia.

Measurements from the base c, 001 on to faces in the zone 001:100.

	Calculated.	I.	II.	III.	IV.	V.	VI.
$c \wedge \Delta$, 209	$14^\circ 59'$						$14^\circ 10'$
$c \wedge \Delta_1$, 207	18 59						17 40
$c \wedge \Delta_2$, 103	21 52			$21^\circ 55'$	$22^\circ 21'$		
$c \wedge \Delta_3$, 205	25 43						25 55
$c \wedge e$, 307	$27^\circ 17\frac{1}{2}'$	$27^\circ 12'$			$27^\circ 11'$		
$c \wedge j$, 102	31 3			31 3			
$c \wedge h$, 203	38 45		$39^\circ 58'$	38 45	38 46	$38^\circ 51'$	37
$c \wedge d$, 101	50 17	51 22	$50^\circ 34\frac{1}{2}'$	50 32	50 25	50 18	50 42
$c \wedge i$, 302	61 $1\frac{1}{2}'$		62 50				61 45
$c \wedge g$, 201	67 27	66 28	67 39	67 8	67 22	67 24	67 24

To the foregoing may be added the measurements of Rose $c \wedge d = 50^\circ 30'$ and $c \wedge g = 67^\circ 36'$, and the following by Spencer: $c \wedge \Delta_3 = 25^\circ 49'$ (mean of $25^\circ 51'$, $25^\circ 55'$, $25^\circ 51'$ and $25^\circ 35'$) and $c \wedge i = 63^\circ$, 63° and $63^\circ 13'$. These last measurements by Spencer and one given by Friedel, $c \wedge i = 62^\circ 50'$, may indicate the existence of a form 805 ($001 \wedge 805 = 62^\circ 34'$) instead of the more probable one i , 302.

Measurements obtained from faces in the zones 100:010 and 010:001.

	Calculated.	I.	II.	V.	VI.
$l \wedge l$, 130 \wedge $\bar{1}30$	$64^\circ 13'$				$64^\circ 22'$
$c \wedge f$, 001 \wedge 011	32 36	$32^\circ 21'$			
$f \wedge f$, 011 \wedge 01 $\bar{1}$	114 48	116 31			
$s \wedge s$, 065 \wedge 06 $\bar{5}$	104 $59\frac{1}{2}'$				105 24
$c \wedge t$, 001 \wedge 021	51 59		$51^\circ 54'$		
$t \wedge t$, 021 \wedge 02 $\bar{1}$	76 2				76 21
$c \wedge u$, 001 \wedge 06 $\bar{1}$	75 $23\frac{1}{2}'$		75 23	$75^\circ 24'$	
$u \wedge u$, 061 \wedge 06 $\bar{1}$	29 13				29 32

Measurements obtained from pyramidal faces.

	Calculated.	I.	VI.	VII.
$q \wedge q$, 863 \wedge 863	126° 21'	126° 31'	126° 21'*	
$q \wedge q$, 863 \wedge 863	138 21		138 21*	
$q \wedge g$, 863 : 863	32 16½	32 18	32 16	
$p \wedge p$, 6·12·7 \wedge 6·12·7	69 38	69 49	69 34	
$p \wedge p$, 6·12·7 \wedge 6·12·7	105 19		105 16	
$p \wedge p$, 6·12·7 \wedge 6·12·7	67 11	67 18½	67 11½	
$c \wedge v$, 001 \wedge 136	20 41		20 18	
$c \wedge r$, 001 \wedge 134	29 31½	30 2½		
$f \wedge r$, 011 \wedge 134	16 40½	16 22		
$d \wedge r$, 101 \wedge 134	40 45½	40 32½		
$c \wedge v$, 001 \wedge 133	37 3		36 45	
$c \wedge \pi$, 001 \wedge 265	42 11		41 46	
$c \wedge \rho$, 001 \wedge 263	56 29		56 12	
$c \wedge \sigma$, 001 \wedge 4·12·5	61 6½		61 8	
$c \wedge \tau$, 001 \wedge 261	77 33		77 32	
$c \wedge a$, 001 \wedge 233	45 44½	----	----	46°
$\Delta_3 \wedge a$, 205 \wedge 233	29 19½			30
$c \wedge \beta$, 001 \wedge 354	50 20			50 28'
$\Delta_3 \wedge \beta$, 205 \wedge 354	71 2			71 9
$d \wedge \beta$, 101 \wedge 354	92 2			92 1
$c^\circ \wedge \gamma$, 001 \wedge 474	58 41			58 43
$\Delta_3 \wedge \gamma$, 205 \wedge 474	42 18½			42 3
$d \wedge \gamma$, 101 \wedge 474	35 34			34 53
$c \wedge \delta$, 001 \wedge 475	52 45			52 25
$c \wedge \epsilon$, 001 \wedge 476	47 37			45 to 47°

In the preceding tables, many of the measurements show considerable variation from the calculated values, which might be expected, owing to the striated character of some of the faces and the small size of others. On the other hand, the measurements from the best and most prominently developed forms, h , d , g , u , q , and p , show a very close agreement with the calculated values, and it is believed that the axial ratio which we have established is more accurate than those given by other investigators.

It is probable that the pyramid x mentioned by Friedel ($c \wedge x = 56^\circ 24'$) is p , 6·12·7 ($c \wedge p$ calculated = $56^\circ 24\frac{1}{2}'$), which is prominently developed on the crystals from Wolfsberg and Huanchaca.

In conclusion, we take great pleasure in expressing our thanks to Professors Friedel and Groth, and Messrs. Cumenge, Hohmann, Spencer, Schott and Fletcher, who have rendered valuable assistance by supplying us with material for this investigation and information concerning the mineral.

Mineralogical-Petrographical Laboratory,
Sheffield Scientific School, February, 1897.