ART. XXXIX.—*Goldschmidtite, a New Mineral*; by WILLIAM H. HOBBS.

THE analyses of Hillebrand and the crystallographical studies of Penfield which were made in connection with the monograph of Cross and Penrose* on the Cripple Creek Mining District have established the fact that the chief telluride ore of the district is the mineral calaverite, containing about three per cent, or less, of silver. The presence of this mineral in the ores had previously been determined by Knight† by chemical analysis. Mr. R. Pearce‡ of Denver had, however, assayed an ore-bearing rock from the Moose Mine, and found it to contain gold, silver, and tellurium in proportions corresponding with sylvanite, so that he believed this mineral to be present. From the complex nature of the material assayed these results can hardly be regarded as conclusive, but to the writer they would seem to indicate at least the probability of the presence of a gold-silver telluride, richer in silver than calaverite, particularly since the output of silver from some of the mines is too large to be fully accounted for by the presence of calaverite alone. Dr. Hillebrand says:

"Notwithstanding that sylvanite has not been identified by positive chemical or crystallographical tests, the evidence of Mr. Pearce as to its presence in some portions of the district at least is entitled to consideration" (l. c., p. 133).

Source of the Material examined.

The material which I have studied was kindly given me for examination by Mr. Gustavus Sessinghaus, a graduate of the Columbia School of Mines, and now a graduate student of the University of Wisconsin. It was obtained from the Gold Dollar Mine in Arequa Gulch, in the extreme southwestern portion of the Cripple Creek Mining District. This mine is located on the northwest quarter of Section 31. (Cf. Plate VII, l. c.) It is near the flank of Grouse Mountain. The material consists of a single small hand specimen, the matrix of which is a breccia in which fragments of granite are conspicuous. Comparison with the gneissose granite of Grouse Mountain shows that the enclosures in the rock have probably been derived from that source. The cementing material of the breccia resembles the phonolite of the region, with

*Geology and Mining Industries of the Cripple Creek District, Colorado: by Whitman Cross and R. A. F. Penrose, Jr. 16th Ann. Report, U. S. Geol. Survey, 1894-5, Pt. II, pp. 1-209.

† Proc. Colo. Sci. Soc., Oct. 1, 1894. ‡ Ibid., April 5, 1894.

which it probably corresponds in composition. The fragments of the breccia are, however, only loosely consolidated, so that the specimen is crossed by numerous irregular cracks, the walls of which are coated with chalcedony.

The crystals of the mineral which is here discussed are firmly attached to the chalcedony, so that great difficulty was experienced in removing them without fracture, particularly as they are possessed of a perfect cleavage. These crystals have a rather long columnar habit with some tendency also to elongated tabular forms with reference to a plane parallel to this axis, and in one or two cases they were observed to have the arborescent forms which have given the name "Schrifterz" to the mineral sylvanite, and have been explained by twinning. The largest individual observed was only about 5^{mm} in length and those which I have succeeded in separating from the chalcedony of the walls would average hardly 2^{mm} in length, with a thickness perhaps a third or a fourth as much. Examination with the lens showed these crystals to be considerably modified and without striation or other distortion, and, except for their minute size, they are admirably suited to measurement. They have a perfect cleavage following the plane of their tabular development. They are seen to be often twins, the plane of twinning following the columnar axis in a direction normal to the cleavage. They are quite brittle and have a hardness of about 2, since they will just scratch the surface of selenite. The amount of material was not sufficient for a satisfactory determination of the specific gravity, but the mineral's composition as recorded below, and the comparison of it with sylvanite and calaverite, make it probable that the specific gravity is very near to 8·6. The luster of the mineral is bright metallic and the color a silver white. The streak is dull, grayish black.

Chemical Composition.

Examined on charcoal before the blowpipe, the mineral readily fuses surrounded by the light bluish green flame which is characteristic of tellurium, leaving on the coal a white coating of tellurium oxide. A yellowish white button of gold and silver results from the fusion, as in the cases of sylvanite and calaverite, though it is much less yellow than the button obtained from the last mentioned mineral. No antimony, sulphur, or selenium could be detected.

A portion of the specimen was broken up and by careful and laborious picking out of the crystals and fragments of crystals about one-tenth of a gram of nearly pure mineral was obtained, which was analyzed and found to contain gold, silver, and tellurium, in the following proportions, the tellurium being estimated by difference:

	Percentage composition.	Ratio.
Au	31·41	·1596
Ag	8·95	·0831
Te	(59·64)	·4771
	100·00	

These proportions correspond almost exactly with the formula Au_2AgTe_6, and show that the mineral is a new species, which I propose to call Goldschmidtite, in honor of my friend, Professor Victor Goldschmidt, of Heidelberg, the inventor of the two-circle goniometer and the author of *Index der Krystallformen* and *Winkeltabellen.*

Below are given in parallel columns the estimated and the theoretical proportions of the constituents of this mineral on the basis of the formula Au_2AgTe_6:

		Calculated.
Te	(59·64)	59·95
Au	31·41	31·44
Ag	8·95	8·61
	100·00	100·00

Relationships with other Tellurides of Gold and Silver.

The mineral sylvanite contains the same elements as Goldschmidtite but in the proportions represented by the formula $AuAgTe_4$.* The mineral calaverite differs in being richer in gold and is not generally credited with a definite formula, because of slight variations noted in the content of silver. The number of analyses of this mineral which have now been made renders it possible, as it seems to me, to arrive at a more definite formula than $(Au,Ag)Te_2$, which assumes an isomorphous relation between gold and silver in the compound that does not exist so far as we know. Comparison of the analyses of calaverite which are given below brings out their striking uniformity with the exception of the silver percentage, and this would seem to indicate that a mineral corresponding to the one having the highest silver percentage (3·52) may form isomorphous mixtures with one that is richer in gold or perhaps entirely free from silver. Since, however, a large proportion of the analyses contain silver in amounts approximating the maximum percentage, it is improbable that isomorphous mixtures occur with tellurides much richer in silver. The formula $Au_9Ag_{\frac{5}{3}}Te_{21}$ seems best to represent the composition of this mineral.

* Groth, Tabellarische Uebersicht der Mineralien, 4te Auflage, Braunschweig, 1898, p. 28.

Analyses of Calaverite.

	Te	Au	Ag	Total
1. California, Genth*	55·89	40·70	3·52	100·11
2. " " †	(56·00)	40·92	3·08	100·00
3. Bowlder Co., Colo. Genth‡	57·67	40·59	2·24	100·50
4. " " " §	57·32	38·75	3·03	99·10
5. Cripple Creek, Colo. Hillebrand‖	57·60	39·17	3·23	100·00
6. " " " ¶	57·40	40·83	1·77	100·00
7. " " " **	57·30	41·80	·90	100·00
Calaverite of formula $Au_9Ag\frac{5}{3}Te_{21}$	57·40	39·08	3·52	100·00

Comparison of the minerals calaverite, Goldschmidtite, and sylvanite brings out the fact that Goldschmidtite is, as regards its composition, intermediate between calaverite and sylvanite and almost exactly half way between them. Together the three minerals represent an homologous series quite analogous to that which has been determined for the minerals of the humite group by Penfield and Howe.†† This will be clear from the following table :

	Te		Au		Ag	
	Per cent.	Ratio.	Per cent.	Ratio.	Per cent.	Ratio.
Calaverite	57·40	·4544	39·08	·1987	3·52	·0327
$Au_9Ag\frac{5}{3}Te_{21}$	(21 = ·4536)		($\frac{27}{3}$ = ·1944)		($\frac{5}{3}$ = ·0363)	
Difference	2·55	·0256	7·54	·0388	5·09	·0473
Goldschmidtite	59·95	·4800	31·44	·1600	8·61	·0800
Au_2AgTe_6	(22 = ·4752)		($\frac{22}{3}$ = ·1584)		($\frac{11}{3}$ = ·0799)	
Difference	2·20	·0176	6·99	·0336	4·79	·0444
Sylvanite	62·15	·4976	24·45	·1244	13·40	·1244
$AuAgTe_4$	(23 = ·4968)		($\frac{17}{3}$ = ·1235)		($\frac{17}{3}$ = ·1235)	

From the above table it is seen that the common difference between consecutive members of the series in ascending order is a gain of Ag_2Te and a loss of $Au\frac{5}{3}$. For purposes of comparison the formulæ of the three minerals should therefore be written :

Calaverite	$Au\frac{27}{3}Ag\frac{5}{3}Te_{21}$.
Goldschmidtite	$Au\frac{22}{3}Ag\frac{11}{3}Te_{22}$.
Sylvanite	$Au\frac{17}{3}Ag\frac{17}{3}Te_{23}$.

The next member of the series should have the formula :

$$Au\frac{12}{3}Ag\frac{23}{3}Te_{24}$$

* This Journal, xlv, 1868, p. 314. † Ibid.
‡ Am. Phil. Soc., xiv, 1874, p. 229. § Ibid., xvii, 1877, p. 117.
‖ 16th Ann. Report U. S. G. S., Pt. II, p. 133. ¶ Ibid. ** Ibid.

Note.—The mineral krennerite is a telluride of gold and silver richer in silver than sylvanite, but the wide and remarkable variations in the proportions of its constituents cause it to be regarded as of very indefinite composition.

†† On the Chemical Composition of Chondrodite, Humite, and Clinohumite. This Journal, xlvii, 1894, p. 188–206.

which is a close approximation to $Au_1Ag_2Te_3$. The mineral krennerite contains silver in about this proportion (19·44 per cent), but the proportions of gold and tellurium do not correspond.

Crystallography of Goldschmidtite.

As already stated, the chief difficulty encountered in measuring the crystals has been their minute size and the consequently small amount of light reflected from their faces. A number of the better faces afforded single images of the signal so that in the prism zone, where the faces were largest, consecutive readings from the same angle showed variations of less than a minute of arc, and on the best crystal the four similar angles between prism and pinacoid were respectively:

61° 42′
61 46
61 46½
61 47½

Considerable confidence is therefore placed in the correctness of the constant which was determined from the angles in this zone, while the values of the other constants are correct only within limits of error which are sufficiently indicated by a comparison of observed and calculated values of readings of interfacial angles. Five crystals have been completely measured and particular angles have been measured also upon other crystals.

The symmetry of the mineral is easily determined as monoclinic, and it is probably also clinohedral. The principal zones of the crystal are those of the axes $\grave{c}$ and $\bar{b}$, a single clinodome and a pyramid which was too small to be determined being the only faces not included in these zones. Owing to the frequent absence and the small development when present of the basal pinacoid, the angle β was determined from the mutual inclinations of the positive and negative unit orthodomes and found to be 89° 11′. The axial ratio $a:b:c$ is 1·8562 : 1 : 1·2981. The crystal forms observed number twenty-two, and are as follows:

Zone of c.— a (100) $i\text{-}\bar{\imath}$; b (010) $i\text{-}\grave{\imath}$; m (110) I; f (210) $i\text{-}\bar{2}$; g (310) $i\text{-}\bar{3}$; t (370) $i\text{-}\grave{\frac{7}{3}}$; l (130) $i\text{-}\grave{3}$.

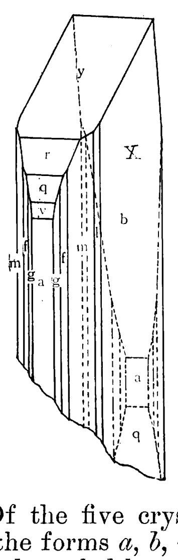
Zone of $\bar{b}$.— y (508) $-\frac{5}{8}\text{-}\bar{\imath}$; s (101) $-1\text{-}\bar{\imath}$; n (201) $-2\text{-}\bar{\imath}$; r (703) $-\frac{7}{3}\text{-}\bar{\imath}$; w (401) $-4\text{-}\bar{\imath}$; q (801) $-8\text{-}\bar{\imath}$; x (10·0·1) $-10\text{-}\bar{\imath}$; v (35·0·1) $-35\text{-}\bar{\imath}$; S ($\bar{1}$01) $1\text{-}\bar{\imath}$; N ($\bar{2}$01) $2\text{-}\bar{\imath}$; W ($\bar{4}$01) $4\text{-}\bar{\imath}$; X ($\bar{1}\bar{0}$·0·1) $10\text{-}\bar{\imath}$; Z ($\bar{1}\bar{4}$·0·1) $14\text{-}\bar{\imath}$; c (001) O.

Zone of $\grave{a}$.—k (032) $\frac{3}{2}\text{-}\grave{\imath}$.

The more important angle readings from which these determinations were made are as follows:

		Obs.	Calc.	Diff.
a : *m*	(100) : (110)	61° 41′*		
b : *m*	(010) : (110)	28 18	28° 19′	−1′
a : *f*	(100) : (210)	42 43	42 52	−9
a : *g*	(100) : (310)	31 55	31 45	+10
b : *l*	(010) : (130)	9 57	10 11	−14
b : *k*	(010) : (032)	26 49	27 18	−29
a : *y*	(100) : (508)	65 7	65 42	−35
a : *s*	(100) : (101)	54 57	54 29	+28
a : *n*	(100) : (201)	34 13	35 17	−64
a : *r*	(100) : (703)	31 40	31 17	+23
a : *w*	(100) : (401)	19 10	19 35	−25
a : *q*	(100) : (801)	10 3	10 6	−3
a : *x*	(100) : (10·01)	7 44	8 7	−23
a : *v*	(100) : (35·01)	2 22	2 20	+2
a : *c*	(100) : (001)	89 25	89 11	+14
b : *c*	(010) : (001)	89 59	90 0	+1
b : *t*	(010) : (370)	12 53	13 0	−7
a : S	(100) : $(\bar{1}01)$	55 35*		
a : N	(100) : $(\bar{2}01)$	34 58	36 0	−62
a : W	(100) : $(\bar{4}01)$	19 18	19 46	−28
a : X	(100) : $(\bar{1}\bar{0}\cdot01)$	7 48	8 9	−21
a : Z	(100) : $(\bar{1}\bar{4}\cdot01)$	5 49	5 44	+5
b : *k*	(010) : (032)	26 49	27 18	−29

1.



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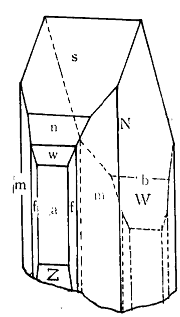

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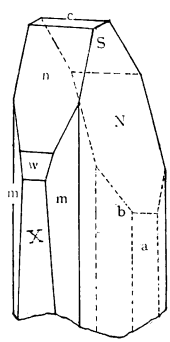


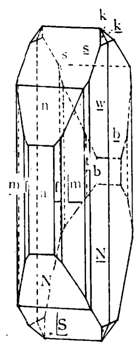
Of the five crystals measured, crystal I (fig. 1) is bounded by the forms *a*, *b*, *m*, *f*, *g*, *l*, *v*, *q*, *r*, *y*, and X. Crystal II (fig. 2) is bounded by *a*, *b*, *m*, *f*, *w*, *n*, *s*, Z, W, and N. Crystal III (fig. 3) exhibits the combination *a*, *b*, *m*, *c*, *w*, *n*, X, N, and S.

Crystal IV (fig. 4) is doubly terminated and represents a simple twin with the twinning plane the orthopinacoid. One of its individuals (the front one in the figure) displays the forms *a*, *b*, *m*, *f*, *t*, *n*, *s*, N, S, and *k*. The other individual differs in having only one positive orthodome (N) and the form *w* in place of *n*. Crystal V (fig. 5) is also a twin crystal, on the front individual of which are developed the forms *a*, *b*, *m*, *c*, *k*, and *s*. The other individual exhibits in addition *n* and lacks the basal pinacoid. A small pyramid lying between *k* and *s* I was unable to determine. All the crystals show a remarkably perfect cleavage following the plane of symmetry.

Crystallographical Affinities of Goldschmidtite and Sylvanite.

As might be expected from its chemical relationship to sylvanite, the mineral Goldschmidtite exhibits affinities also in its crystal development. Both minerals have monoclinic symmetry and somewhat similar forms are developed upon them. Ten of the twenty-two forms discovered on Goldschmidtite have representatives on sylvanite. Below are given in parallel columns the crystallographical constants of the two minerals and some of the angle readings between faces of corresponding forms. It will be noted that the differences are greatest in the prism zone, where the largest faces of Goldschmidtite make the error of reading comparatively small. The orientation of sylvanite is that of Schrauf, which is now generally adopted.

4.



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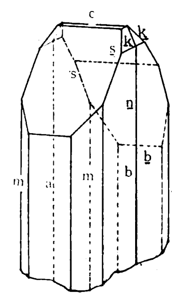

The axes $\dot{a}$ and $\dot{c}$ are each about one-seventh longer in Goldschmidtite than in sylvanite. It is to be regretted that satisfactory material is not available for the crystallographical study of calaverite. That studied by Penfield* was so poor that he was unable to determine the crystallographical constants. He thinks the mineral is probably triclinic, with its angles somewhat similar to those of sylvanite. It lacks the pinacoidal cleavage of that mineral but is observed in twins according to the face of (101). When suitable material is available for study it will be interesting to see whether relations between the lengths of the crystallographical axes and the proportions

* l. c., p. 135.

of its constituent elements, can be discovered, as has been done in the case of the minerals of the humite group.

Goldschmidtite	Sylvanite
Au_2AgTe_6	$AuAgTe_4$.
Monoclinic	Monoclinic
$\beta = 89° 11'$	$\beta = 89° 35'$
$a : b : c$	$a : b : c$
1·8562 : 1 : 1·2981	1·6339 : 1 : 1·1265
Perfect cleavage (010)	Perfect cleavage (010)
Common twinning plane (100)	Common twinning plane (101)
Columnar axis, c	Columnar axis parallel to (101)

	Angles.	Angles.	Diff.
$a : m$	61° 41′	58° 32′	+3° 9′
$b : m$	28 18	31 28	−3 10
$f : a$	42 42	39 15	+3 27
$s : a$	54 57	54 57	
$S : a$	55 35	54 52	+ 43
$n : a$	34 13	35 48	−1 35
$n : s$	20 43	19 9	+1 34
$a : N$	34 58	35 16	— 18
$c : a$	89 25	89 35	— 10
$S : N$	20 37	19 36	+1 1

Conclusions.

1. Goldschmidtite is a new mineral species of composition represented by the formula Au_2AgTe_6.

2. It occupies an intermediate position exactly half way between calaverite and sylvanite.

3. Calaverite, Goldschmidtite, and sylvanite form together an homologous series, analogous to that of the minerals in the humite group, the common difference being the addition of Ag_2Te and the subtraction of $Au\frac{5}{3}$ in passing from any one of the series to the next above it.

4. Goldschmidtite has monoclinic symmetry with β 89° 11′, and $a : b : c$, 1·8562 : 1 : 1·2981. It exhibits no less than twenty-two crystal forms, most of which are in the zones of c and $\bar{b}$.

5. Crystallographically as well as chemically Goldschmidtite shows affinities with sylvanite, ten forms being common to the two minerals, though they are referred to axial unities of which $\acute{a}$ and $\acute{c}$ are each about one-seventh longer in Goldschmidtite than in sylvanite.

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