

ART. XL.—*Notes on Tellurides from Colorado*; by
CHARLES PALACHE.

1. *Sylvanite from Cripple Creek.*

THE presence of sylvanite among the telluride ores of Cripple Creek was first made known by the analysis of Pearce,* and the considerable silver content of the ores was credited by him, in large part at least, to that mineral. His analysis however was made on massive material, and the lack of crystallographic evidence of the presence of sylvanite, together with the failure of other investigators to find the mineral, led to some mistrust of his results and the silver content of the ores was doubtfully attributed to the common ore, calaverite, which was known to carry a small percentage of silver.

Of recent years, however, crystallized sylvanite appears to have been found in considerable amount in several of the Cripple Creek mines and it is the purpose of this paper to describe a series of sylvanite crystals which offer most satisfactory proof of the correctness of Pearce's original conclusion.

The crystals to be described were placed at the writer's disposal for examination by Professor Hobbs of the University of Wisconsin, to whom they had been presented by Mr. F. M. Woods of Victor, Colorado, the collector. The crystals were in two lots labelled respectively: "Sylvanite," Mabel M. Property, Beacon Hill, Victor; and "Calaverite," Victor, Col.

All proved to be alike sylvanite and consisted of isolated crystals and crystal fragments varying in size from 1^{mm} to 8^{mm} in greatest dimension. The color is pure silver-white and many of the fragments display the perfect cleavage parallel to the clinopinacoid which is characteristic of this mineral and serves well to distinguish it from the more common calaverite. The specific gravity, determined on three isolated crystals on the hydrostatic balance, was 8.161.

The dominant habit of the crystals is thin tabular parallel to $b, 010$, the edges of the tables being bounded by planes of the orthodome zone. The tables are frequently as thin as paper and the edge planes become too small to be measurable. A second well-marked habit is prismatic, determined by the pronounced development of the zone of the positive unit pyramid and orthodome, (111) and (101), and other pyramids of this zone. As will be seen from the figures, crystals of this habit are frequently rich in forms, some of which proved to be new to the mineral.

* Proc. Colo. Sci. Soc., 1894.

A skeletal development, well known on sylvanite from other localities, is common on these crystals; but it did not affect the character of the crystal planes which were in general brilliant, giving good reflections.

Measurements were made on the two-circle goniometer and the adjustment of the crystals was rendered very accurate by the use of the three pinacoids, nearly always all present.

The following twenty-nine forms were observed on the five crystals measured:

<i>c</i> , 001	<i>m</i> , 101	<i>r</i> , 111	<i>u</i> ,* 723
<i>a</i> , 100	<i>n</i> , 201	<i>w</i> ,* 343	II, 341
<i>b</i> , 010	N, $\bar{2}$ 01	<i>s</i> , 121	<i>y</i> , 123
<i>R</i> , 120	<i>d</i> , 011	<i>o</i> , 131	ρ , $\bar{1}$ 11
<i>e</i> , 110	<i>v</i> ,* 525	<i>q</i> , 141	σ , $\bar{1}$ 21
<i>f</i> , 210	γ , 212	<i>i</i> , 321	<i>J</i> , $\bar{3}$ 21
<i>g</i> , 310	<i>t</i> , 323	<i>j</i> ,* 521	κ , $\bar{5}$ 21
			<i>Y</i> , $\bar{1}$ 23

In the following table are given the computed and measured angles for the four new forms. The forms *o*, 131, *q*, 141 and II, 341 while not new, have not been observed since Miller's studies, and are here added, with their computed angles, in order to complete the tables of Goldschmidt by whom they were omitted as uncertain. The new form *u*, 723, is the most interesting, occurring in nearly all the measured crystals with good development and being apparently characteristic for this locality.

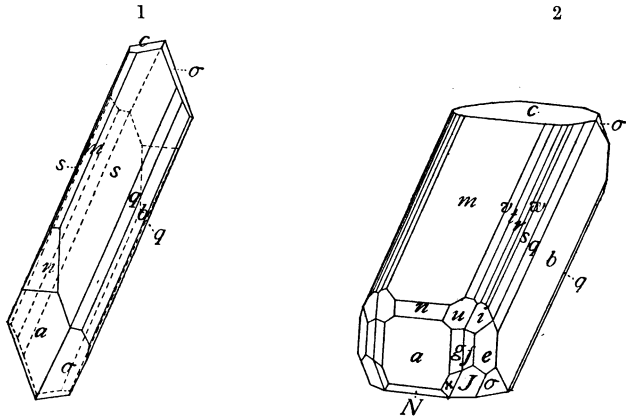
Letter.	Miller symbol.	Computed angle.		Average measured angle.		Variations.				Number of observations.	Quality of faces.
		ϕ	ρ	ϕ	ρ	ϕ		ρ			
						+	-	+	-		
<i>v</i>	525	57°·06'	39°·41'	57°·03'	39°·36'	12'	13'	7'	3'	5	fair
<i>w</i>	343	24·53	58·52	24·49	58·57	9	8	7'	6	2	poor
<i>u</i>	723	65·04	60·42	65·01	60·36	14	5	12	15	6	good
<i>j</i>	521	56·53	76·22	56·50	76·25					1	excel-
II	341	24·44	78·36								lent.
<i>o</i>	131	11·39	73·50								
<i>q</i>	141	8·47	77·38								

The figures illustrate the typical prismatic habit, as shown in various combinations of planes. In fig. 1 the pyramids are developed at the expense of orthodome and clinopinacoid; in fig. 2 the latter forms predominate, giving a tabular-prismatic character to the crystal. This zone of pyramids is generally

* Forms marked thus are new.

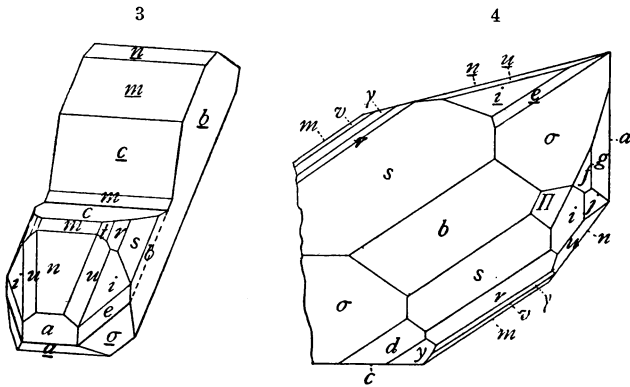
rich in forms as shown in fig. 2 and is sometimes deeply striated. It forms a satisfactory means of distinguishing the positive from the negative octants, which in its absence, owing to the nearness of the angle β to 90° in sylvanite, is not always easy to do.

Of the other pyramidal forms, σ , $\bar{1}21$, is the most common, being rarely absent and generally relatively large in size. The other pyramids, both positive and negative, and the prisms are



of very subordinate importance in defining the outlines of the crystals.

Two of the measured crystals were found to be twinned according to the common law for sylvanite, twinning plane the



orthodome, 101. Figs. 3 and 4 reproduce these twinned crystals in about the proportions of the originals. Fig. 3 will be seen to be a simple contact twin, in which, however, the two

individuals, in contact along the plane 101, are very unlike in development. The crystal figured in normal position is bounded by numerous positive pyramids and domes while the twinned individual is much larger and a much simpler combination. The reëntrant angle between the two basal planes with the intervening narrow portion of the twinning plane 101 made the twinned character of the crystal quite evident. In a subordinate development this mode of twinning is quite frequent, the twinned individual appearing as a narrow transverse ridge on the surface of the *m* plane of a larger simple crystal such as shown in fig. 2.

A less simple phase of the twinning is represented in fig. 4 in orthographic projection on 010, where apparently no plane boundary exists between the two individuals. The planes \underline{n} , \underline{u} , \underline{z} , and \underline{e} , constituting the upper part of that figure were only recognized as in twin position by the complex symbols which they yielded in the projection, whose study, in the light of the simple twin already observed, showed their true nature. It is possible, however, that this is a contact twin like No. 3; for the remaining forms shown in the upper part of fig. 4, *s*, *r*, *v*, etc., are not affected in their position by the twinning; but in the absence of the planes bounding the opposite end of the crystal the course of the twinning boundary cannot be accurately defined.

A chemical analysis was made upon about .5 grams of the sylvanite crystals, which were carefully picked over under the lens until apparently entirely freed from adhering gangue. The analysis shows, however, that considerable of the siliceous gangue was still present. The composition is that of a normal sylvanite, Au,AgTe_4 .

	Sylvanite.	Cal. to 100%.	Mol. ratio.	
Insol.	1.02			
Au	26.09	26.25	.1334	} = 1
Ag	12.49	12.57	.1164	
Te	60.82	61.18	.4894	} = 1.96
Fe	1.19			
Total	101.61	100.00		

2. *Crystallographic Identity of Goldschmidtite with Sylvanite.*

In 1899, Hobbs* described goldschmidtite, a new silver-gold telluride, intermediate in composition between sylvanite and calaverite. The analysis was made on a very small amount of material and seemed therefore open to question, but the crystallographic results appeared to place the mineral distinctly

* This Journal, vii, 357, 1899.

apart from others. Through the kindness of Professor Hobbs the writer was entrusted with two of the five type crystals of the new mineral for examination and thus familiar with its appearance, recognized it again in a specimen in the Harvard collection secured some time before from Cripple Creek and labelled as from the Little May Mine. Several measurable crystals were obtained from the latter specimen and they were found to agree in general with the two type crystals of goldschmidtite examined. The author's measurements of Hobbs' two type crystals confirmed in general his results as shown by the table of angles given below but the use of the two-circle goniometer made possible the measurement of a number of minute pyramid planes which Hobbs had been compelled to leave undetermined. These same forms and some additional ones were also found on the new material, thus confirming the identity of the two specimens. These pyramid forms, projected on the goldschmidtite axes, gave symbols far from simple, and unsatisfactory relations with the other forms. They were studied in gnomonic projection, and a comparison of such a projection of the goldschmidtite forms on the clinopinacoid with a similar projection of sylvanite forms showed a striking analogy between the two. By making the orthopinacoid 100 of goldschmidtite equivalent to the orthodome 101 of sylvanite many forms of the first become identical with known forms of the second, and the remainder, while apparently new to sylvanite, receive comparatively simple symbols on the sylvanite axes. In the following table the agreement of angles of the common forms in the two principal zones is well shown.

Symbols Goldschm.	Symbol Sylvanite.	Obs. (Hobbs).	Obs. (Palache).	Calc. (Sylvanite).
100 : 110	=101 : 121	61° 41'	61° 41'	61° 35½'
100 : 210	=101 : 111	42 43	42 56	42 45
100 : 230	=101 : 131	----	70 11	70 10
100 : 310	=101 : 323	31 55	31 40	31 38½
100 : $\bar{1}01$	=101 : 100	55 35	55 15	55 08
100 : 201	=101 : 001	34 13	34 16	34 27
$\bar{1}01$: 201	=100 : 001	89 48	89 31	89 35
100 : 001	=101 : $\bar{2}01$	89 25	88 38	88 48
100 : 401	=101 : 201	19 18	19 30	19 20

Much had been learned concerning the crystallographic character of goldschmidtite when the sylvanite crystals above described came to hand, and their study helped to clear up and make certain the relation between the two minerals. The general similarity between the habit and forms of the two series of crystals led to a surmise that a concealed twinning

like that found in the sylvanite crystals was also present in goldschmidtite, giving rise to the many apparently new forms referred to above. And a comparison of the measurements and projections finally proved that this was the case for most of these forms. The following table shows the sylvanite forms equivalent to those observed on goldschmidtite. It will be observed that it is divided into three parts containing (1) forms given by Hobbs and reobserved by the author; (2) forms observed by the author only; and (3) forms given by Hobbs which were not observed on any of the author's material and which lead to new forms for sylvanite.

(1)				(2) (cont'd)			
Forms observed by Hobbs and Palache.				Additional Forms observed by Palache			
Goldschmidtite.		Sylvanite.		Goldschmidtite.		Sylvanite,	
Letter.	Symbol.	Letter.	Symbol.	Symbol.	Letter.	Symbol.	
<i>c</i>	001	<i>N</i>	201	134	<i>J</i>	321	
<i>b</i>	010	<i>b</i>	010	112	<i>κ</i>	521	
<i>a</i>	100	<i>m</i>	101	230	<i>o</i>	131	
<i>g</i>	310	<i>t</i>	323	120	<i>q</i>	141	
<i>f</i>	210	<i>r</i>	111	832	<i>I</i>	211 twinned	
<i>m</i>	110	<i>s</i>	121	532	<i>i</i>	321	
<i>k</i>	032	<i>θ</i>	231	532	<i>i</i>	321 twinned	
<i>w</i>	401	<i>n</i>	201 twinned	734	<i>j</i>	521 twinned	
<i>n</i>	201	<i>c</i>	001	102	<i>M</i>	101	
<i>s</i>	101	<i>a</i>	100 twinned				
<i>S</i>	101	<i>a</i>	100				
<i>N</i>	201	<i>c</i>	001 twinned				
<i>W</i>	401	<i>n</i>	201				
(2)				(3)			
Additional Forms observed by Palache.				Forms observed by Hobbs not confirmed by Palache and yielding new sylvanite forms.			
Goldschmidtite.		Sylvanite.		Goldschmidtite.		Sylvanite.	
Symbol.	Letter.	Symbol.	Letter.	Letter.	Symbol.	Symbol.	
232	<i>e</i>	110		<i>t</i>	370	292	
232	<i>e</i>	110 twinned		<i>l</i>	130	161	
434	<i>f</i>	210		<i>v</i>	35·0·1	9·0·10?	
434	<i>f</i>	210 twinned		<i>w</i>	10·0·1	403 twinned	
212	<i>g</i>	310		<i>q</i>	801	203	
212	<i>g</i>	310 twinned		<i>r</i>	703	{ 2·0·25 or	
131	<i>R</i>	120				{ 301 twinned	
234	<i>ρ</i>	111 twinned		<i>y</i>	508	{ 708 or	
132	<i>σ</i>	121		<i>X</i>	10·0·1	{ 801 twinned	
132	<i>σ</i>	121 twinned		<i>Z</i>	14·0·1	504	

The forms in (3) appear to need confirmation before being added to the sylvanite series as the following considerations will show. None of them was observed by the author on the

twelve or more supposed goldschmidtite crystals from the Little May Mine measured by him nor on the complex sylvanite crystals from the same region. In the absence of definite statements concerning the quality or frequency of occurrence of particular forms in the paper by Hobbs it is difficult to know what weight to assign to these forms. *t*, 292 and *l*, 161, are pyramids of the principal zone of sylvanite and may well be good forms. The seven remaining forms are orthodomies. Of these, two, *q*, 203 and *X*, 403 with its twin, *x*, 403 are probably good forms as they have simple symbols and agree closely in angle with calculated position:

			Meas.	Calcul.
<i>q</i> , 203	^	001	24° 37'	24° 20'
<i>X</i> , 403	^	001	42 34	42 36
<i>x</i> , 403 twin	^	001	26 25	26 24

v, 9·0·10, stands only 2° 20' from the dominant form 101 and may be vicinal to it; *r*, 2·0·25, is inclined but 3° 10' to 001, of which it is very likely a vicinal; *y*, 708, is inclined 3° 27' to 101 and may be vicinal to it; lastly *Z*, 504 is inclined 2° 16' to 403 and might be considered vicinal to that form were it confirmed.

It seems evident in the light of the above facts that so far as crystallographic character is concerned goldschmidtite can not be distinguished from sylvanite but represents a peculiar habit of that mineral, common, as shown in the preceding paper, to the sylvanite of Cripple Creek. Fig. 1 of the preceding paper on sylvanite illustrates fairly well the prevailing habit of goldschmidtite when in the sylvanite position, except that *σ*, 121, should be very minute, and most crystals are simple contact twins.

The results of this study were submitted to Prof. Hobbs in the hope that he might be able to complete them by a new analysis of the type material on a larger amount of substance. This proves unfortunately to be impossible, since the specimen from which the type crystals were obtained was only temporarily in his hands and is not now available.

In default of this analysis it was thought that it might be worth while to determine the composition of the supposed goldschmidtite from the Little May Mine, and by sacrificing the whole specimen and carefully picking the crushed gangue material enough was obtained (about 0·4 gram) for an analysis. This purpose was, however, defeated by an accident early in the work, so that only the gold content could be determined. For the sake of comparison this is given below together with that of goldschmidtite and sylvanite.

Little May Mine.	Goldschmidtite.	Sylvanite	AuAgTe ₄ .	Sylvanite Cripple Creek.
Au 28·89	31·44	24·45		26·09

While little weight can be attached to a comparison based thus on a defective analysis, still it seems clear that the material studied differs but little from the typical goldschmidtite in composition. On the other hand, while the gold content is high when compared with that of the theoretical AuAgTe_2 , it should be clearly remembered that no sylvanite with exactly that composition has been as yet analyzed, the gold content actually found varying from 25.87 per cent to 29.35 per cent with proportionately varying silver content. These results seem to show conclusively that the ratio of gold to silver in sylvanite may vary considerably from the theoretic proportion of 1 : 1, without affecting the physical characteristics materially, and it is a question whether it is advisable to attempt to establish species based upon these variations of composition.

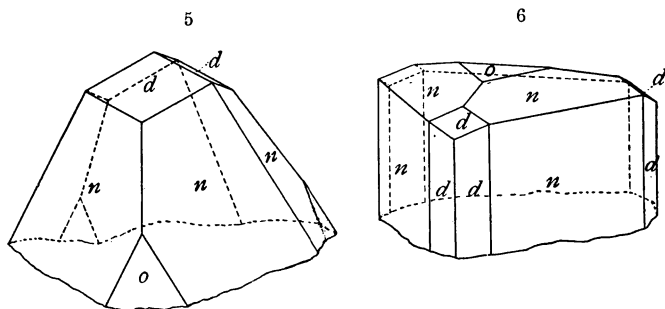
Note by Professor W. H. Hobbs.—In view of the results of the investigation by Dr. Palache, above detailed, it seems proper for me to say that the name goldschmidtite should be withdrawn from mineralogical literature as representing a distinct mineral species. Dr. Palache's study shows that goldschmidtite can be referred to the same set of axes as sylvanite, of which it represents a peculiar type. This being true my analysis, which had to be made on an extremely small amount of material, must contain a large error. The method used was the oxidation of the tellurium on charcoal, weighing the button of combined silver and gold, and, after solution of the silver, weighing the gold in the form of powder. The danger of this method lies in the possibility that tellurium will not be completely eliminated and that some silver will oxidize. The button obtained was, however, bright and apparently freed from tellurium. I regret that material is not now available for a second analysis, yet in view of Dr. Palache's crystallographic study of better material, checked as it has been by analysis, no course is open to me but to discredit the results of my analysis.

3. *Hessite Crystals from Colorado.*

A specimen of well-crystallized hessite from Boulder Co., Colorado, has been recently acquired by the Harvard Mineral Cabinet from Mr. G. B. Frazer. A description of this specimen is here offered because the crystals present certain interesting peculiarities of habit and because so far as the author has been able to discover no crystals of this mineral from the United States have yet been figured.

The specimen consists of a small fragment of bluish vein quartz in one side of which is a drusy, quartz-lined cavity. On the quartz walls of the cavity are eight or ten brilliant hessite crystals, a millimeter or less in height, and two small

tufts of wire gold. Two of the steel-gray hessite crystals and a small irregular fragment were detached, the latter yielding before the blowpipe the characteristic reactions of hessite.



The two crystals (figs. 5, 6) which are shown in about their natural proportions in the figures, presented two entirely different habits, both hexagonal in appearance; but measurements proved them to be isometric and combinations of the three forms:

o , (111); d , (101); and n , (211).

The hexagonal appearance is due to the development about a trigonal axis, an axis, that is, normal to an octahedral face, and in order to bring out the peculiar symmetry of the distortion the drawings have been made with this trigonal axis vertical, as though the crystals were truly hexagonal.

The difference in habit is due to the fact that different faces of the above forms are developed on the two crystals. In the one, six faces of the trapezohedron equally inclined to the trigonal axis give the effect of a scalenohedron whose summit is modified by a rhombohedron composed of three faces of the dodecahedron, while three octahedron faces form a steeper rhombohedron of the same sign. In the other crystal the habit is prismatic; three only of the six trapezohedron faces parallel to the trigonal axis are developed, yielding a trigonal prism whose edges are beveled by the prism of second order, that is by six planes of the dodecahedron; the termination consists of positive and negative rhombohedrons consisting of dodecahedron and trapezohedron faces respectively, and a single face of the octahedron forming a basal pinacoid.

The two habits were represented about equally on the other crystals in the cavity as far as could be judged without their removal. It should be said that the faces present were sharp and clear and no trace of the missing faces of any form could be detected.