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GOLDSCHMIDTINE, A NEWLY RECOGNIZED ANTIMONIDE OF SILVER

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Introduction

The numerous early analyses of natural antimonial silvers listed by Hintze (1904, p. 429) give silver values ranging from 71.52 to 84 per cent. Several of these analyses correspond well to the composition Ag_3Sb (72.7 per cent Ag), which is the generally accepted formula for the mineral dyscrasite. The correctness of this formula has been confirmed by Machatschki (1928) who showed that bladed dyscrasite from Andreasberg in the Harz has the same hexagonal or nearly hexagonal structure as the artificial compound Ag_3Sb. Antimonial silvers with more than 73 per cent Ag, such as the material from Cobalt, Ontario, described by Walker (1921), are inhomogeneous, consisting of dyscrasite and a material with higher silver content.

The crystal form attributed to dyscrasite is orthorhombic, pseudohexagonal, with common twinning on (110). The accepted elements:

$$a:b:c=0.5775:1:0.6718$$

rest on meagre measurements by Hausmann (1847, p. 57), probably made on crystals from Andreasberg. Machatschki noted the fact that Hausmann's elements gave a prism angle of practically 60°, but could find no further relation between the form ascribed to dyscrasite and the hexagonal lattice of natural and artificial Ag_3Sb.

A specimen with well developed crystals, labeled dyscrasite from Andreasberg (Harvard Mineralogical Museum, 81628) offered an opportunity of revising the early crystallographic work on this mineral. Satisfactory goniometric measurements gave orthorhombic elements in fair agreement with Hausmann's values; x-ray measurements confirmed the choice of lattice and defined its dimensions; but a calculation of the cell content, using the formula Ag_3Sb and the specific gravity 9.7—the mean of several concordant published values—gave an unsatisfactory result. Remeasurement of the specific gravity gave a much lower value, namely 6.83; but again an improbable cell content was obtained. Finally, a pure sample was prepared and carefully analysed by F. A. Gonyer who reported a surprising result: instead of Ag_3Sb, the composition of the mineral proved to be Ag_2Sb, which accounted for the low specific gravity and yielded an integral cell content.

Since there is no question regarding the existence of the mineral with the composition Ag_3Sb, to which the name dyscrasite[1] is firmly attached, it is clear that the morphology attributed to dyscrasite is that of a mineral with the composition Ag_2Sb whose individuality has hitherto not been recognized. With the consent of Frau Geheimrat Goldschmidt, the mineral with the composition Ag_2Sb is named *Goldschmidtine*,[2] in memory of Victor Goldschmidt [1853–1933] of Heidelberg, whose kindly teaching has led three generations of students to an appreciation of the beauties of crystal morphology.

This work was carried out mainly in the Harvard Mineralogical Laboratory on material and with facilities kindly placed at my disposal by Professor Charles Palache. My thanks are also due to Dr. Harry Berman for making an independent determination of the specific gravity of goldschmidtine; to Dr. J. A. Harcourt for assistance in examining polished sections; to Mr. F. A. Gonyer for carrying out the analysis; and to Mr. W. E. Richmond for taking the *x*-ray photographs.

MORPHOLOGY

Appearance of the crystals. The specimen from Andreasberg shows groups of goldschmidtine crystals, which are between tin-white and silver-white with bright metallic lustre on fresh surfaces, pale lead-gray and dull when tarnished. The goldschmidtine is associated with abundant poorly crystallized galena, veinlets of silver or antimonial silver and specks of ruby silver in a gangue of calcite.

The crystal groups of goldschmidtine reach 3 mm. in greatest size. Although imperfectly developed, due to mutual interference and contact with the associated minerals, the general shape is easily recognized as that of a short six-sided prism with a broad base, the edges between the prism and the base being truncated by narrow faces. Already in the hand specimen it is clear that the six-sided prisms are not hexagonal individuals, but complex groups of crystals twinned on planes in the prismatic zone. In spite of the generally poor development, good goniometric measurements were obtained from some portions of selected crystal groups. These showed that goldschmidtine is orthorhombic, univer-

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[1] New observations confirming and extending Machatschki's data on dyscrasite will be reserved for another communication. These show that dyscrasite differs from the newly recognized mineral in all its essential properties

[2] Goldschmidtite of Hobbs (1899) was shown by Palache (1901) to be identical with sylvanite.

~~sally twinned on (110)~~, as described later. With considerable angles between the subparallel faces in twinned relation, it was easy to distinguish the faces of a single individual and thus obtain a projection of the untwinned reciprocal lattice.

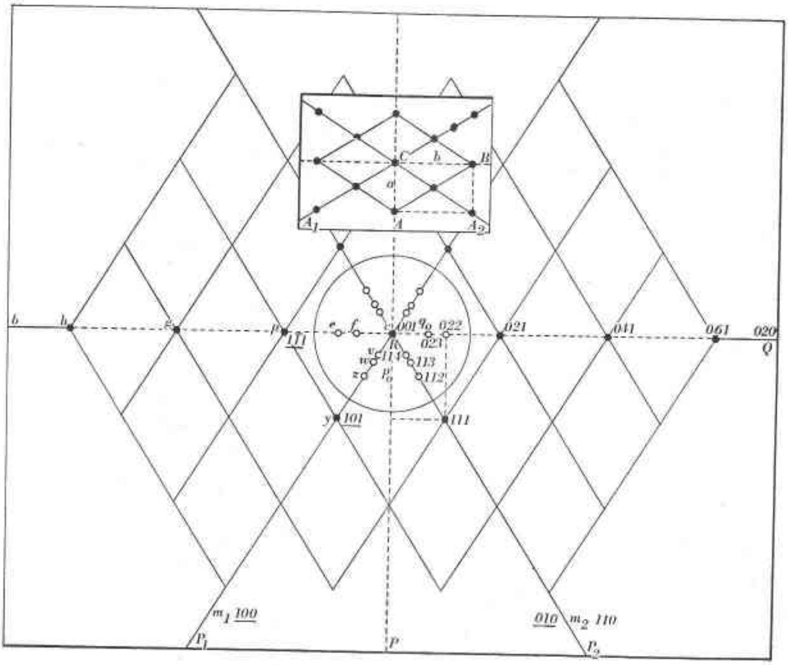

FIG. 1. Goldschmidtine. Gnomonic (reciprocal lattice) projection of the observed forms. The underlined indices refer to the axes P_1P_2R of the simple (principal) reciprocal lattice cell; the indices not underlined refer to the double (base-centered) reciprocal lattice cell with axes PQR. The inset shows the corresponding direct lattice, the simple cell with axes A_1A_2C, the double cell with axes ABC.

Determination of the crystal lattice from the crystal form. This was conveniently done by applying the Harmonic-Arithmetic Rule (1937) to the gnomonic projection of the observed planes. This rule is a rigorous consequence of an idealized form of the Law of Bravais, as applied to the simple structural lattice. It states that, if the relative importance of crystal faces is a direct expression of the relative spacings of the corresponding lattice planes, then the gnomonic projection points of the faces of a zone-quadrant form simultaneous series:

$$\begin{array}{llllllllllllllllll}
p: & 0 & \cdots & \frac{1}{3} & & \frac{1}{2} & & & & 1 & & & & 2 & & & 3 & \cdots & \infty \\
s: & 0 & & & \cdots & (\frac{2}{4}) & & \frac{2}{3} & & (\frac{2}{2}) & & \frac{3}{2} & & (\frac{4}{2}) & & \cdots & & & \infty \\
t: & & & & & \cdots & \frac{3}{5} & & \frac{3}{4} & (\frac{3}{3}) & \frac{4}{3} & & \frac{5}{3} & & \cdots & & & & \infty \\
 & & & & & & & & & \cdots & & & & & & & & &
\end{array}$$

in which the end-terms represent the planes with the greatest and second greatest spacings while the unit term represents the plane with the third greatest spacing in the quadrant.[3] The primary series (p) is always the most strongly developed; the secondary (s), tertiary (t) and higher series are successively weaker and often entirely absent. The harmonic and arithmetic parts of each series are equally developed only if the spacings of the planes represented by the end-terms are about equal. In general, either the harmonic or the arithmetic part will preponderate with reduction or complete suppression of the other part.

Figure 1 gives a gnomonic projection of the observed forms of goldschmidtine on the plane normal to the axis of the main (prismatically developed) zone. Our problem is, in the first instance, to find what we shall call the *principal lattice cell*, that is the lattice cell whose axial planes are the three sets of non-coaxial lattice planes with the greatest spacings. From the Law of Bravais it follows that the main zone of a crystal contains two of the axial planes of the principal lattice cell. The vertical axial planes must therefore be chosen from the planes $m_1\,m_2\,b$. Since the symmetry is orthorhombic, $m_1\,m_2$ are the only possible vertical axial planes; c is necessarily the third axial plane. The polar axes of the principal lattice cell are therefore $P_1\,P_2\,R$, with reference to which the axial planes are $m_1(100)$, $m_2(010)$, $c(001)$.[4]

It remains to determine unit planes defining the relative lengths of the cell-edges; and since the axes $P_1\,P_2$ are equivalent it suffices to determine, say, the unit plane (101) in the axial zone $[cm_1]$ of the principal lattice cell. From the definition of the principal lattice cell the planes with the greatest spacings in the zone quadrant $[cm_1]$ are $c(001)$ and $m_1(100)$; the plane with the third greatest spacing is (101). Inspecting the zone series c—m_1 in the gnomonic projection we see at once that y is the only admissible unit term. With c—y as unit length we have a regular primary series in which the harmonic part alone is present:

	c	v	w	z	y	m
p:	0	$\frac{1}{4}$	$\frac{1}{3}$	$\frac{1}{2}$	1	∞

The plane y is therefore the plane with the third greatest spacing in the zone quadrant and consequently it is the plane (101) of the principal lattice cell. Thus the structural lattice is completely defined. Confirmation is given by the zone series c—b where p is the unit term of a regular primary series in which the harmonic and arithmetic parts are equally developed:

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[3] The derivation of these ideal series from the Law of Bravais was outlined to the Mineralogical Society of America at the meeting in 1936. A similar derivation with further study of zonal series has recently been given by Donnay (1938).

[4] In figure 1 indices referring to the principal lattice cell are underlined.

	c	*f*	*e*	*p*	*g*	*h*	*b*
p:	0	$\frac{1}{3}$	$\frac{1}{2}$	1	2	3	∞

The plane *p* is therefore the unit plane $(1\bar{1}1)$ in the principal lattice cell.

The harmonic-arithmetic rule thus yields an unequivocal determination of the simple reciprocal structural lattice, whose first layer is given by the net in full lines carrying the filled points (*hkl*) at its nodes. The direction lines to the vertical planes are parallel to vectors leading from the origin (000) to zero-layer points (*hk*0); the blank points are points in which vectors joining the origin (000) to higher layer points (*hkl*) intersect the plane of the first layer (plane of the gnomonic projection). The inset in figure 1 shows the corresponding direct lattice with A_1A_2C as the axes of the principal lattice cell.

With reference to the rectangular reciprocal lattice cell, with axes $P\ Q\ R$ (dotted in figure 1) and elements $p_0:q_0:r_0$ there is systematic absence of points not conforming to the law, $(h+k)$ even; the direct rectangular lattice cell, with axes $A\ B\ C$ (dotted in the inset, figure 1) and elements $a:b:c$, is therefore base-centered (*C*). Since we recognize the faces of a crystal as planes of the crystal lattice, and see a direct relation between the relative importance of crystal faces and the relative spacing of lattice planes (and the intimately connected relative simplicity of indices), the indices used to describe the forms of a crystal must surely conform to the mode of the lattice. The indices of the observed forms of goldschmidtine are therefore as given in Table 1, in which the indices of only two forms, *b*{020} and *e*{022} must be written in multiple form to give $(h+k)$ even. In both cases the resulting reduced spacing and increased complexity of indices is in keeping with the relative importance of the form.

It is now of interest to compare the form list of goldschmidtine with a list of lattice planes and spacings extending from (001), with the greatest spacing in the lattice, to (061), the observed plane with the least spacing (Table 1). The spacings were determined by a rapid graphical method described elsewhere (1938), the values being given in absolute units based on the value $c_0 = 8.42$ Å subsequently obtained by *x*-ray measurement.

In excellent agreement with the Law of Bravais, the most important forms of goldschmidtine, *c m b p y*, correspond to the most widely spaced planes of the lattice; the remaining observed forms (with letters), and some further forms (with queries) attributed to dyscrasite (Goldschmidt, 1916) but probably observed on goldschmidtine, are separated by increasing gaps in the list. These gaps do not affect the choice of lattice, which is amply confirmed by the arrangement of the principal forms;

Table 1. Goldschmidtine: Spacings of Planes in the Base-Centered Lattice

Form	*hkl*	*d*(Å)	*Form*	*hkl*	*d*(Å)	*Form*	*hkl*	*d*(Å)
c	001	8.42	—	221	3.05	—	203	2.27
m	110	6.57	*g*	041	2.89	—	151	2.26
b	020	6.16	?	202	2.85	?	133	2.21
y	111	5.17	—	132	2.75	—	312	2.16
p	021	4.96	*w*	113	2.58	—	223	2.13
?	200	3.88	*f*	023	2.55	—	331	2.11
—	201	3.77	—	310	2.53	—	242	2.08
?	130	3.60	—	311	2.41	—	043	2.07
z	112	3.55	?	240	2.41	—	152	2.04
e	022	3.47	?	150	2.35	*v*	114	2.01
—	131	3.32	—	241	2.31	*h*	061	1.99

they do, however, represent departures from perfect correspondence between form-importance and lattice spacing. One might, therefore, fairly ask: If the Harmonic-Arithmetic Rule follows rigorously from the idealized Law of Bravais, why is the Rule strictly satisfied in the present case whereas the Law is only approximately true? This is easily understood if we regard the departures from perfect agreement between form importance and lattice spacing not as under-development of certain expected planes but as over-development in certain zones. As may be seen in Table 1 all the observed planes after *p* lie in the two important zones [100] and [1$\bar{1}$0]. This over-development simply extends these zonal series, thereby adding precision to the selection of the unit term. And thus we see that over-development in certain zones, a frequent departure from ideal correspondence between form-importance and lattice spacing, is a help rather than a hindrance in finding the crystal lattice by means of the serial expression of the Law of Bravais.

Elements and angles. The best goniometric measurements give the following geometrical elements for goldschmidtine:

$$p_0:q_0:r_0=1.0868:0.6860:1$$
$$a:b:c=0.6312:1:0.6860$$

Hausmann's elements, supposed to have been obtained on dyscrasite:

$$a:b:c=0.5775:1:0.6718$$

are only roughly similar to the new values. A comparison of angles is perhaps more significant:

	Hausmann	Peacock
(110):(1$\bar{1}$0)	60°01′	64°31′
(001):(011)	33 54	34 27

The angles (001):(011) and consequently the ratios $b:c$ are fairly close; the considerable difference in the angles (110):(1$\bar{1}$0) and therefore in $a:b$, is very probably due to Hausmann's having taken this value as 60° for lack of a good measurement, whereas the true angle actually departs from 60° by 4½°.

The forms attributed to dyscrasite (Goldschmidt, 1916) are also those of goldschmidtine. Of the twelve forms observed in the present work, *c*{001}, *b*{010}, *m*{110}, *e*{011}, *p*{021}, *z*{112}, *y*{111}, are given for dyscrasite. The remaining forms ascribed to dyscrasite, *a*{100}, *n*{120}, *q*{130}, *r*{150}, *d*{101}, *x*{332}, *s*{133}, are also probable forms of goldschmidtine, the indices of the more complex forms, *q*, *r*, *x*, *s*, conforming to the base-centered condition, $(h+k)$ even. Finally, the oft repeated figure representing dyscrasite is a typical goldschmidtine combination: *c b m p z y*. It is evident, therefore, that the early crystallography of antimonial silver was based on crystals with the composition Ag_2Sb while the early analyses were made on dyscrasite, or mixtures of antimonial silvers of higher average silver content.

Table 2 gives a summary of the best measurements on goldschmidtine and the corresponding calculated two-circle and interfacial angles. The angles A, B, C have the following significance:

$$A=(hkl):(100);\ B=(hkl):\ (010);\ C=(hkl):\ (001)$$

TABLE 2. GOLDSCHMIDTINE—Ag_2Sb
Orthorhombic—C; disphenoidal—222
$a:b:c=0.6312:1:0.6860$; $p_0:q_0:r_0=1.0868:0.6860:1$

Forms	Measured		Calculated			
	ϕ	ρ	ϕ	$\rho=C$	A	B
c 001	—	0°00′	—	0°00′	90°00′	90°00′
b 020	0°00′	90 00	0°00′	90 00	90 00	0 00
m 110	57 44	90 00	57 44½	90 00	32 15½	57 44½
f 023	0 00	25 15	0 00	24 34½	90 00	65 25½
e 022	0 00	34 25	0 00	34 27	90 00	55 33
p 021	0 00	53 55	0 00	53 55	90 00	36 05
g 041	0 00	70 46	0 00	69 58½	90 00	20 01½
h 061	0 00	76 00	0 00	76 20½	90 00	13 39½
v 114	57 50	18 09	57 44½	17 48½	75 00½	80 36
w 113	57 44	23 39	57 44½	23 11½	70 33	77 52
z 112	57 43	32 43	57 44½	32 43½	62 48	73 13½
y 111	57 44	52 10	57 44½	52 07	48 08	65 05

The good agreement between the mean measured and calculated angles for the common forms, *m e p z y*, shows that the geometrical elements are sufficiently precise.

Character of the forms. The following notes describe the frequency and quality of the observed forms.

c{001}: large on most crystals; surface good; usually faintly striated along [$\bar{1}$10] as a result of poor cleavage or parting on (110); separate segments in twinned groups usually slightly displaced from true parallelism due to slight misfit of twinned parts.

b{020}: large on all crystals; surface poor, but gives good azimuth readings; always distinctly striated along [100] or stepped by oscillatory combination with planes (0*kl*).

m{110}: large on most crystals; surface good; always faintly striated in an oblique direction by very narrow planes (*hkl*); oblique striations often symmetrical to a plane (001) passing through the middle of the crystal.

f{023}: observed twice as a very narrow face.

e{022}: fairly common as a good narrow face.

p{021}: on all crystals as a good face; usually wider than *e*.

g{041}, *h*{061}: rare and usually narrow.

v{114}, *w*{113}: each observed three times as narrow faces of fair quality.

z{112}, *y*{111}: common and often well developed; *y* usually wider than *z*.

As already mentioned the further forms ascribed to dyscrasite were probably observed on goldschmidtine:

$$a\{200\},\ r\{150\},\ q\{130\},\ n\{240\},\ d\{202\},\ x\{332\},\ s\{133\}$$

These may be retained subject to confirmation.

Twinning and crystal class. Crystals of goldschmidtine are all twinned by reflection and composition on the planes (110) or (1$\bar{1}$0). Twinning on this law results in complete restoration of the crystal lattice with some deviation at the twinning plane (Fig. 9). The obliquity of the twin, given by the angle between the normal to the twin plane (110) and the quasi-normal lattice row [310] is 4° 25′, which is larger than the values usually found in this common type of twinning. Planes of *b*{020} on the normal individual and *m*{110} on the twinned individual make the calculated angle 6° 46′, as compared with the mean angle 6° 43′ from four measurements. Planes of *e*{022} and *z*{112}, *p*{021} and *y*{111}, and other pairs likewise come into subparallel position on the two individuals. In the valuable explanatory terminology of Friedel (1926, p. 421) this twin law is an example of *twinning by pseudo-merohedry*. This designation conveys the fact that the crystal (orthorhombic) is pseudo-merohedral (pseudohexagonal) and therefore predisposed to twin on the elements of hexagonal pseudosymmetry.

Twinning on (110) is rarely simple. Sometimes it is repeated on parallel planes giving successive plates alternately in normal and twinned positions; occasionally the twinning is truly lamellar in some parts of the intergrowth. More commonly the twinning takes place on both planes of {110}, giving a variety of cyclic intergrowths similar to the well known twinned groups of aragonite. As shown in Fig. 9 the "misfit" on a cyclic group of three individuals is considerable. Theoretically this gives a pronounced gap, or overlap, according to the arrangement of the intergrowths. Actually such misfits are covered by irregular growths. Although the patterns of the groups can be easily distinguished the crystal groups are always more or less malformed.

In addition to the very evident twinning on (110) goldschmidtine shows evidence of twinning on other laws which have important bearing on the crystal class. The already mentioned symmetrical oblique striations on $m\{110\}$, shown in Fig. 8 and frequently visible, are perhaps possible in the holohedral class; but in crystals attached at one end of the vertical axis they rather suggest twinning on (001). More convincing is a notching of the edges [100] by terminal planes in symmetrical relation to (100), illustrated in Figs. 6 and 7; this was observed several times, and it can be explained only by twinning on (100). If (001) and (100) are twinning planes they cannot be symmetry planes of the crystal. In the orthorhombic system the absence of two symmetry planes excludes both the dipyramidal and pyramidal classes and admits only the disphenoidal class—222.

Twinning on a symmetry element of the crystal lattice which is not a symmetry element of the crystal structure was termed *twinning by merohedry* by Friedel. As shown in Fig. 10 such twinning precisely restores the lattice (obliquity zero), whereas the merohedral structure, indicated by two points with only disphenoidal symmetry in each cell, is brought into reflection relation. Since the lattices of the two individuals fit equally well on any junction surface the complete irregularity of this surface in most twins by merohedry is easily understood. As the obliquity is zero we should expect that the twinning would be difficult to detect, especially if the twinned parts are equally developed or intimately intergrown. Under these conditions it is also difficult or impossible to distinguish the complementary merohedral forms. Such is the case with goldschmidtine in which a distinction between right and left disphenoids is not practicable.

The final step in the morphological study is to attempt to determine the space group from Donnay and Harker's generalization of the Law of Bravais (1937). As a better approximation than the Law of Bravais, the generalization states that the importance of crystal planes is proportional to the effective spacings of the corresponding lattice planes, as defined by the lattice parameters and the simplest indices conforming to the general extinctions of the space group.

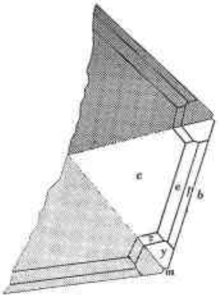

FIG. 2

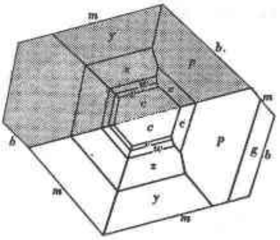

FIG. 4

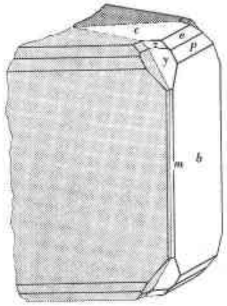

FIG. 3

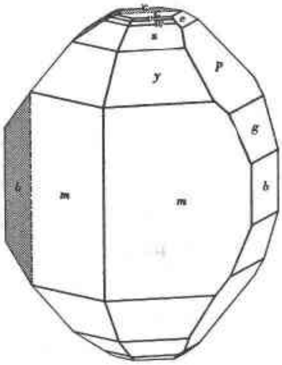

FIG. 5

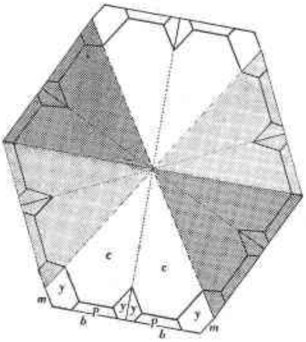

FIG. 6

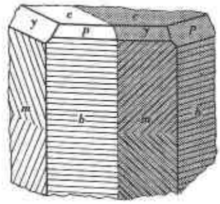

FIG. 8

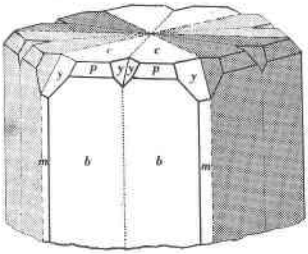

FIG. 7

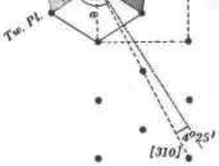

FIG. 9

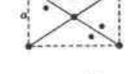

FIG. 10

EXPLANATION OF FIGURES 2–10.

FIGS. 2, 3. An incomplete cyclic group resulting from twinning on $(1\bar{1}0)$ and $(\bar{1}\bar{1}0)$, showing the commonly large development of *c* and *b*.

FIGS. 4, 5. Twin on $(\bar{1}\bar{1}0)$ with unusually large development of terminal planes.

FIGS. 6, 7. A cyclic group (restored) showing twinning on $(1\bar{1}0)$ and $(\bar{1}\bar{1}0)$ and also twinning on (100).

FIG. 8. Fragment of a twin showing the usual juxtaposition of a horizontally striated plane *b* on one individual and an obliquely and symmetrically striated plane *m* on the other individual

FIG. 9. The direct lattice twinned by pseudomerohedry on (110) and $(1\bar{1}0)$ with obliquity 4°25′.

FIG. 10. The direct lattice twinned by merohedry on (100), bringing a schematically represented disphenoidal structure into reflected position.

In the disphenoidal class there are only two space groups in a one-face centered lattice, $C222$ and $C222_1$. In $C222$ there is no general condition beyond that imposed by the lattice and the effective spacings are as given in Table 1; in $C222_1$ a vertical screw axis gives effective halving of the spacing of the basal planes. The importance of $c\{000\}$ certainly ranks with that of $m\{110\}$ and $b\{020\}$ and not after that of $p\{021\}$ as it should with the halved spacing of 4.21 Å; therefore we could choose the space group $C222$. However, the space group $C222_1$ is given by the systematic absence of the odd orders of $(00l)$ in the x-ray photographs. Isolated exceptions do not, of course, invalidate an approximation. It would strengthen the generalized Law of Bravias, however, if it were shown to explain the development of crystal forms better than the classical law in a large number of special cases.[5]

STRUCTURE CELL

Lattice and space group. On a small crystal of goldschmidtine the following x-ray photographs were taken with copper radiation: rotation, zero-layer and first-layer Weissenberg about [001], and a zero-layer Weissenberg about [100]. The crystal proved to be twinned on (110); but with the considerable obliquity of the twin the diffractions from the two individuals were easily distinguished.

The lattice parameters obtained for the rectangular cell are:

$$a_0=7.75 \text{ Å},\ b_0=12.32 \text{ Å},\ c_0=8.42 \text{ Å, all} \pm 0.05 \text{ Å}$$
$$a_0:b_0:c_0=0.629:1:0.683$$

in good agreement with the geometrical ratio:

$$a:b:c=0.6312:1:0.6860.$$

The films showed diffractions (hkl) only with $(h+k)$ even, proving the base-centering of the lattice found by morphological study. Furthermore diffractions $(00l)$ are present only with l even. In the disphenoidal class these systematic extinctions admit only one space group, $C222_1$.

Specific gravity and cell content. A small clean crystal (0.1571 gm.) weighed with proper precautions in air and in water, gave the specific gravity:

$$G=6.83$$

In view of this unexpectedly low value Dr. Berman kindly made an independent determination, using the method of attaching the crystal

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[5] Since this was written Dr. Donnay has added great weight to the generalized law of Bravais, in a paper read to the Mineralogical Society of America, December, 1938: Crystal space-groups determined without x-rays (Abstract in *Am. Mineral.*, **23**, no. 12, part 2, p. 5, 1938).

(0.0065 gm.) to a small glass rod and suspending the whole in a heavy liquid. The value thus obtained was 6.7. With the higher specific gravity the molecular weight of the contents of the base-centered cell is:

$$M_C=3328$$

On a clean sample of crystal fragments (0.34 gm.) Mr. Gonyer reported the values in the first column of Table 3.

TABLE 3. GOLDSCHMIDTINE: COMPOSITION AND CELL CONTENT

	1	2	3	4	5
Ag	64.78	0.6488	0.006013	20.01	63.9
Pb	0.00	—	—	—	—
As	0.00	—	—	—	—
Cu	0.00	—	—	—	—
Sn	0.00	—	—	—	—
Sb	35.01	0.3506	0.002896	9.64 } 9.70	36.1
S	0.06	0.0006	0.000019	0.06	
	99.85	1.0000			100.0

1. Goldschmidtine, Andreasberg, Harz; anal. F. A. Gonyer. 2. Weight proportions summing to unity. 3. Atomic proportions. 4. Atoms in the cell with molecular weight 3328. 5. Percentage composition of Ag_2Sb.

As shown in the fourth column, Table 3, the content of the base-centered cell closely approaches:

$$Ag_{20}Sb_{10} \text{ or } 10[Ag_2Sb]$$

The calculated specific gravity is:

$$G_0=6.92$$

CHEMICAL CONSIDERATIONS

The composition Ag_2Sb has been mentioned in the past as one of many possible silver-antimony compounds. Rammelsberg (1875, p. 26) notes that Domeyko obtained 64 per cent Ag on material from Chanarcillo, Chile. If this material was a homogeneous silver-antimony mineral it was presumably goldschmidtine. Following earlier systematists, Groth (1874, p. 14) also suggested the composition Ag_2Sb on the basis of a supposed analogy between the silver mineral and chalcocite. Since there is no simple structural relation between goldschmidtine and chalcocite this speculation is without significance.

The silver-antimony equilibrium diagram (Guertler, 1913, p. 769) shows only one compound, Ag_3Sb (dyscrasite) which crystallizes at 560°. This indicates that Ag_2Sb does not form from fusion conditions. To test this a crystal was heated in a partial vacuum for 15 minutes at 520° to 530°. The crystal melted and, on cooling, solidified to a black bead which gave an *x*-ray powder photograph not resembling a powder diagram of goldschmidtine. The crystal had evidently dissociated to a mixture of phases as predicted by the equilibrium diagram in the region corresponding to the composition Ag_2Sb.

PHYSICAL PROPERTIES

Goldschmidtine has no good cleavage. A difficult separation, probably a parting, was obtained parallel to (110). The cleavages {001} and {011} attributed to dyscrasite seem to have been based on the striations noted on goldschmidtine. The hardness is $2\frac{1}{2}$, which is notably lower than the hardness $3\frac{1}{2}$–4, given for dyscrasite.

Polished sections were made of a single crystal group and of fragments from the sample used for analysis. The mineral is homogeneous, tin-white inclining to silver-white; distinctly anisotropic in the crystal section, which was cut roughly parallel to [001]. A polished section of antimonial silver from Cobalt, Ontario, was examined for comparison. The section showed anisotropic dyscrasite, verified by an *x*-ray powder photograph which conformed exactly to Machatschki's data (1928), and a lighter isotropic material which is presumably silver with some antimony in solid solution. In separate specimens no clear difference could be noticed in the appearance of goldschmidtine and dyscrasite in reflected light. *X*-ray powder photographs on samples extracted with the useful micro-drill devised by Harcourt (1937) afford a sure means of distinction.

SUMMARY

Goldschmidtine—Ag_2Sb, is a distinct mineral hitherto confused with dyscrasite—Ag_3Sb. Lattice: orthorhombic; base-centered. Class: disphenoidal. Geometrical elements: $a:b:c=0.6312:1:0.6860$. Forms: *c*{001}, *b*{020}, *m*{110}, *f*{023}, *e*{022}, *p*{021}, *g*{041}, *h*{061}, *x*{114}, *w*{113}, *z*{112}, *y*{111}. Habit: stout prismatic with *c b m* dominant. Twinning: on (110), also on (100) and (001). Space group: $C222_1$. Base-centered structure cell: $a_0=7.75$ Å, $b_0=12.32$ Å, $c_0=8.42$ Å, all ±0.05 Å; $a_0:b_0:c_0=0.629:1:0.683$; contains $Ag_{20}Sb_{10}$. Cleavage: none; parting (?) {110}. Hardness: $2\frac{1}{2}$. Specific gravity: 6.83 (meas.); 6.92 (calc.). Tin-white to silver-white with metallic lustre; lead-gray when tarnished. Polished surfaces homogeneous, anisotropic. Analysis (Gonyer): Ag 64.78, Sb 35.01, S 0.06=99.85. Occurrence: with galena, native silver or antimonial silver and ruby silver, in calcite on a specimen from Andreasberg, Harz. Name: after Victor Goldschmidt [1853–1933] of Heidelberg.

Goldschmidtine is used to exemplify the method of determining the structural lattice from the crystal form, by applying the Harmonic-Arithmetic Rule to the gnomonic projection of the observed forms.

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