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Contributions to the Study of Pyrargyrite and Proustite.

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CONTENTS.

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§ 1. Historical Survey.

THE labour of tracing the history of the Red Silver Ores, of collating the literature, and of tabulating the crystalline forms previously observed, has been, to a large extent, rendered unnecessary by the memoir published by E. Rethwisch (*Neues Jahrbuch für Mineralogie*, Beilage Band iv. (1886), pp. 31-109), under the title "Beiträge zur mineralogischen und chemischen Kenntniss des Rothgültigerzes."

If due care be taken to correct the errors, which are discussed below, the memoir of Rethwisch may be taken as a summary and analysis of the facts known about the crystallographic and chemical characters of the Red Silver Ores up to the year 1886.

(*a.*) Prior to that date there had been a great want of precision in the observations upon the two minerals; very few analyses had been made upon carefully selected material; the rhombohedron angle of Pyrargyrite had been variously given by competent observers as from 71° 18′ to 71° 42′, and that of Proustite as from 72° 10′ to 72° 45′; a very large number of crystal forms had been recorded, but these had not been critically examined, neither had it been determined which belong to Pyrargyrite and which to Proustite. Sella, by whom a large number of the forms were first given (Quadro delle forme cristalline dell' Argento Rosso, &c. *Il Nuovo Cimento* iii. (1856) p. 287), abandoned his original intention of writing a monograph of these minerals, and contented himself with a bare list of the forms; whereby numerous valuable observations made by him in several European museums have been lost to science.

The intermediate varieties of Red Silver, containing both antimony and arsenic, were commonly assumed to be intermediate in colour and in rhombohedron angle between Pyrargyrite and Proustite.

From the occurrence of the form $\{2\bar{1}\bar{1}\}$ ∞R as a trigonal prism, and from the habit of the few doubly terminated crystals which had been found, it was supposed that Pyrargyrite is hemimorphic, but it had not been found possible to distinguish the forms characteristic of the two ends.

Twinning on the face (211) $\frac{1}{4}R$ had been fully and accurately described by Haidinger.[1] Descriptions had been given of Pyrargyrite and Proustite twinned on (100) R, and of Pyrargyrite twinned on (111) $0R$. Twinning on (110) $-\frac{1}{2}R$, on $(2\bar{1}\bar{1})$ ∞R, and on $(11\bar{1})$ $-2R$, had been recorded by different observers.

For references to the scanty information published regarding the physical characters of the two minerals the memoir of Rethwisch should be consulted, as also for details of previous chemical and crystallographic observations.

To the list of the previous literature given by Rethwisch the following must be added:—

1795. Freiesleben. *Bemerkungen über den Harz* (passim).
1811. Sowerby. *Exotic Mineralogy.* I. Plate xxxiii.
1824-5. Haidinger. *Edinburgh Journal of Science,* Vol. I. p. 326; Vol. II. p. 91.
1836. Mohs. *Naturgeschichte,* I. p. 252.
1846. Domeyko. *Annales des Mines,* IX. p. 365.
1851. Sénarmont. *Annales de Chimie et de Physique,* XXXII. p. 171.
1853. Breithaupt. *Berg-und Hüttenmännische Zeitung,* XII. p. 401.
1856. Vogl. *Gangverhältnisse u. Mineralreichthum Joachimsthals,* p. 81.
Sella. *Mem. Accademia Torino,* XVII. p. lxix. *Nuovo Cimento,* IV. p. 93.
1863. Nöggerath. *Ber. nieder-rheinische Gesellschaft,* XX. p. 51.
Ihne. *Berg-und Hüttenmännische Zeitung,* XXII. p. 51.
1882. Daubrée. *Bull. Société Minéralogique de France,* V. p. 300.
vom Rath. *Ber. nieder-rheinische Gesellschaft,* p. 31.
1885. Schenck. *Zeitsch. f. Krystallographie,* X. p. 283.
1886. Rethwisch. *Neues Jahrbuch, Beilage Band* IV. p. 31.
Streng. *Neues Jahrbuch,* (I.) p. 60.
Schuster. *Verh. geologische Reichsanstalt,* p. 68.
1887. Schuster. *Zeitsch. f. Krystallographie,* XII. p. 117.
Goldschmidt. *Krystallographische Projectionsbilder,* V. VI.
Purgold. *Isis,* 1886, p. 53.
1888. Miers and Prior. *Mineralogical Magazine,* VII. p. 196.
Goldschmidt. *Index der Krystallformen.*

(*b.*) Subsequently to 1886.

E. Rethwisch (loc. cit.) contributes analyses and measurements made upon four specimens, of which one is a pure Proustite, another a pure Pyrargyrite, and the remaining two are Pyrargyrite containing 2·62 and

[1] *Edinburgh Journal of Science* (1825), Vol. II. p. 91.

3·01 per cent. of arsenic respectively, the special object being to determine the true dimensions of the two former. This is the first attempt which was made to analyse measured crystals of either mineral, *i.e.* to gain precise knowledge of their composition and form and of the relations which may exist between them.

The four specimens appear to constitute a gradual series both as regards the percentage of arsenic, the rhombohedron angle, and the specific gravity. Unfortunately, the two intermediate varieties, though from different localities, are practically identical, and the dimensions of the Pyrargyrite are not satisfactorily determined either as regards the accuracy of the measurements or their suitability. In fact, when these observations are criticised, it will be seen (vid. *Min. Mag.* vii. p. 199, and below § 6) that they lead rather to the conclusion that the specimen of pure Pyrargyrite has the same rhombohedron angle as the two arsenical varieties.

This author's observations, therefore, do not serve to establish any gradual passage between Pyrargyrite and Proustite, neither do they determine the dimensions of Pyrargyrite; the facts added to our knowledge are: (1) a specimen of Proustite had a rhombohedron angle 72° 10′, and specific gravity 5·55; (2) two specimens of Pyrargyrite containing 3 per cent. of arsenic had a rhombohedron angle 71° 22′, and specific gravity 5·72 to 5·75; (3) a specimen of pure Pyrargyrite had a rhombohedron angle perhaps a little lower than 71° 22′, specific gravity 5·87.

The crystallographic data of this memoir are fully criticised below (§ 9).

Max Schuster called attention to the striations upon the prism $\{10\bar{1}\} = \infty P2$ of Pyrargyrite, and to the manner in which they indicate faces belonging to different forms at the two ends of the crystal, and so prove beyond doubt its hemimorphic character; he also showed how this character has escaped attention owing to the peculiar mode of twinning.[1]

In the two specimens from Andreasberg described by him there is a tendency to the formation of steep negative and flat positive scalenohedra at the attached end, and of steep positive and flat negative scalenohedra at the unattached end of the crystals.

The mode of twinning was described as unsymmetrical and explicable by hemitropy about the normal to the prism faces $\{10\bar{1}\}$, $\infty P2$; the two individuals are so united that their prism faces coincide and form a single column, towards the middle of which meet the two ends characterised by steep negative scalenohedra. In a doubly terminated twin crystal of this

[1] Schuster does not seem to have been aware that this twinning had been previously described and figured by Naumann (*Lehrb. der Kryst.* 1830, Vol. II. p. 311, Fig. 721).

nature the hemimorphic character would be disguised, the terminations are similar, and it is only by careful observation of the markings on the prism, and of the direction to which they tend, that the twin-structure and the lines of junction can be made out.

Finally, a note by Mr. G. T. Prior and myself contributes measurements and analyses of Proustite containing at least 1·41 per cent. of antimony, and shows that in this case the rhombohedron angle is 72° 12′, the same as that of pure Proustite,[1] and the specific gravity 5·64.

V. Goldschmidt, in his *Projectionsbilder*, selected from the forms found by Rethwisch in the earlier literature those which he regards as beyond suspicion, and by means of elaborate gnomonic projections showed the zonal distribution and position of these forms as compared with those of calcite and quartz. In his *Index der Krystallformen*,[2] where earlier observations are thoroughly discussed, it is suggested that the equal development of zones radiating from the prisms $\{10\bar{1}\}$, $\infty P2$, and $\{2\bar{1}\bar{1}\}$, ∞R, is a characteristic feature of the Red Silvers. (See on this point § 22.)

From the above summary it will be seen that the chief points which require to be established are the following:—

(1). Are Pyrargyrite and Proustite two distinct species, or do they pass into one another?

(2). If distinct species, what are the crystallographic, physical, and chemical characters of each?

(3). If there are intermediate varieties, what are their characters and what relations do they possess?

(4). If Pyrargyrite is hemimorphic, what are the forms characteristic of the two ends of the crystal?

It may reasonably be expected that some light would be thrown upon questions concerning the internal structure of crystals by a complete discussion of the forms on these minerals, which are so rich in faces, especially if it is possible to distinguish the forms which are characteristic of Pyrargyrite from those which are characteristic of Proustite, and to discriminate between the faces which belong to the two ends of hemimorphic crystals.

§ 2.—Results.

The present paper is the result of a study of the rich collection of Red

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[1] The locality of the pure Proustite mentioned on p. 201 should be Mexico, not Chañarcillo.

[2] I am indebted to Dr. Goldschmidt for the loan of this part of the Index before its publication.

Silvers in the British Museum (Natural History). The analyses have been made by Mr. G. T. Prior, and the specific gravity determinations in most instances by both Mr. Prior and myself.

The following are the conclusions at which we have arrived :—

(1). Proustite and Pyrargyrite are two species which may be always distinguished.

(2). Proustite has a rhombohedron angle 72° 12′; Pyrargyrite a rhombohedron angle 71° 22′. The specific gravities of the pure minerals are, Proustite 5·57, Pyrargyrite 5·85.

(3). The minerals may be perfectly distinguished by the colour of their powder. The powder of Proustite is scarlet-vermilion, the powder of Pyrargyrite purplish-red.

(4). Pyrargyrite is certainly hemimorphic; Proustite is probably so.

(5). Among the forms which occur on the two minerals, some are characteristic of Proustite, some of Pyrargyrite, and some are common to both. These are distinguished below.

(6). Among the forms which occur on Pyrargyrite, some are characteristic of one end of the crystal, some of the other, and some are common to both. These are also distinguished so far as is possible.

(7). Most Pyrargyrite contains arsenic, and some Proustite contains antimony. Such specimens rarely yield crystals which can be accurately measured; where the percentage is large it is generally due to a visible association of Proustite and Pyrargyrite, and produces a confused crystallisation.

(8). Where the percentage is small and the crystals can be measured with perfect accuracy, the presence of antimony in Proustite and of arsenic in Pyrargyrite does not appreciably affect the rhombohedron angle.

(9). Pyrargyrite is twinned upon the faces $\{211\}$, $\frac{1}{4}R$; $\{100\}$, R; $\{10\bar{1}\}$, $\infty P2$; $\{110\}$, $-\frac{1}{2}R$; Proustite upon the faces $\{211\}$, $\frac{1}{4}R$; $\{100\}$, R; $\{111\}$, $0R$; $\{110\}$, $-\frac{1}{2}R$. Taking into account the hemimorphism of Pyrargyrite, the twins on (211) and (100) are always explicable by hemitropy about those faces and not about the rhombohedron edge lying in them. (211) is also a plane of secondary twinning in Pyrargyrite.

(10). The principal zones in Pyrargyrite are very rich in vicinal faces and in forms with high indices; these zones are determined by the rhombohedra $\{110\}$, $-\frac{1}{2}R$; $\{100\}$, R; and the prisms $\{10\bar{1}\}$, $\infty P2$; $\{2\bar{1}\bar{1}\}$, ∞R; the vicinal faces have positions which may be expressed as regular functions of their indices.

(11). The richest portions of the principal zones are those in which they approach most nearly to faces of the forms $\{10\bar{1}\}$, R; $\{10\bar{1}\}$, $\infty P2$; and $\{2\bar{1}\bar{1}\}$, ∞R, not lying in the zone.

(12). All the typical forms lie in zones with simple symbols containing either $\{100\}$, R, or $\{110\}$, $-\frac{1}{2} R$.

(13). The two minerals are strictly rhombohedral in character, no typical forms occur in both the direct and inverse ($+$ and $-$) positions.

The more purely mineralogical details, description of individual specimens, localities from which certain forms and combinations have been observed, &c., are omitted from this paper, and reserved for the complete catalogue of the specimens in the Museum collection.

§ 3.—Description of Pyrargyrite and Proustite.

Pyrargyrite.—Rhombohedral, hemimorphic.

$100 : 010$ $(R : R) = 71° \, 22'$; $100 : 111$ $(R : 0R) = 42° \, 20\tfrac{1}{2}'$.

$a : c = 1 : 0{\cdot}7892$.

Observed Forms.

a	$10\bar{1}$	*f'*	$7\bar{2}\bar{5}$	*T*	$4\bar{1}\bar{1}$	ξ	610
b	$2\bar{1}\bar{1}$	*g'*	$12\ 1\ \bar{4}$	*U*	$91\bar{2}$	π	$19\ 11\ \overline{12}$
c	$40\bar{3}$	*m'*	$82\bar{3}$	*V*	$13\ 1\ \bar{4}$	ρ	$64\bar{3}$
d	$21\bar{1}$	*p'*	$12\ \bar{5}\ \bar{6}$	*W*	$92\bar{3}$	σ	$41\bar{1}$
e	110	*r'*	16 1 1	*X*	$8\bar{3}\bar{4}$	τ	$3\bar{1}\bar{2}$
f	$22\bar{3}$	*s'*	$70\bar{3}$	*Y*	$81\bar{3}$	υ	320
? *g*	$71\bar{2}$	*t'*	$18\ 4\ \bar{7}$	*Z*	$50\bar{4}$	φ	510
? *k*	$11\ 1\ \bar{4}$	*w'*	$50\bar{1}$	*F'*	$40\ 7\ \overline{11}$	ψ	$30\bar{1}$
l	$62\bar{3}$	*x'*	$26\ 5\ \bar{7}$	*G'*	810	ω	530
n	$40\bar{1}$	*B*	$17\ 5\ \bar{4}$	*I'*	$17\ 0\ \overline{11}$	τ'	830
? *o*	111	*C*	$12\ 1\ \bar{3}$	*N'*	$17\ 0\ \overline{15}$	π'	$90\bar{7}$
p	210	*D*	$54\bar{8}$	*P'*	$61\bar{2}$	Γ	$33\bar{4}$
q	$32\bar{4}$	*E*	$21\bar{2}$	*Z'*	$13\ 9\ \overline{11}$	Δ	$19\ 0\ \overline{13}$
r	100	*F*	$9\ 5\ \overline{10}$	α	$42\bar{3}$	Ξ	$27\ 6\ \bar{7}$
s	$11\bar{1}$	*G*	$43\bar{6}$	β	$5\bar{1}\bar{4}$	Π	$8\bar{1}\bar{1}$
t	310	*H*	$8\ 5\ \overline{10}$	γ	$50\bar{3}$	Σ	13 7 0
u	211	*I*	611	δ	$32\bar{1}$	Υ	520
v	$20\bar{1}$	*L*	$19\ 4\ \bar{5}$	ε	$20\ 11\ \bar{7}$	Γ'	730
w	410	*N*	$53\bar{6}$	ζ	$90\bar{5}$	Δ'	$17\ 0\ \overline{13}$
y	$30\bar{2}$	*P*	$32\bar{3}$	η	$28\ 13\ \overline{17}$	Π'	13 6 0
z	$51\bar{2}$	*Q*	$15\ 1\ \bar{3}$	θ	$97\bar{8}$	Ω'	$74\bar{8}$
a'	$72\bar{1}$	*S*	$86\bar{7}$	λ	11 4 0		

Twin-face; (1) *u*. (2) *r*. (3) *a*. (4) *e*. (5) *b* (?).

Cleavage; (1) *r*. (2) *e*; imperfect. Fracture, conchoidal.

H = 2·5, G = 5·85 (varying between 5·85 and 5·77 in the arsenical varieties).

Colour; by reflected light, black to grey-black; by transmitted light, reddish-purple.

Streak (colour of powder); purplish-red.

Translucent to opaque.

Composition, $3Ag_2S.\ Sb_2S_3$; generally contains a small percentage of arsenic.

PROUSTITE.—Rhombohedral; probably hemimorphic.

$100 : 010\ (R : R) = 72° 12'$; $100 : 111\ (R : 0R) = 42° 52'$.

$a : c = 1 : 0·8038$.

OBSERVED FORMS.

a	$10\bar{1}$	*r*	100	*n'*	$7\bar{1}\bar{4}$	θ'	720
b	$2\bar{1}\bar{1}$	*s*	$11\bar{1}$	*M*	$63\bar{2}$	Δ	$19\ 0\ \overline{13}$
d	$21\bar{1}$	*t*	310	*P*	$32\bar{3}$	Φ	$13\ 2\ \bar{3}$
e	110	*u*	211	*a*	$42\bar{3}$	Ψ	621
? *h*	$55\bar{4}$	*v*	$20\bar{1}$	γ	$50\bar{3}$		
? *o*	111	*w*	410	ζ	$90\bar{5}$		
p	210	*y*	$30\bar{2}$	τ	$3\bar{1}\bar{2}$		

Twin-face; (1) *u*. (2) *r*. (3) *o*. (4) *e*.

Cleavage; *r*, imperfect. Fracture, conchoidal.

H = 2·5,[1] G = 5·57 (varying between 5·58 and 5·64 in the antimonial varieties).

Colour; by reflected light, black to reddish-black; by transmitted light, vermilion.

Streak (colour of powder); scarlet-vermilion.

Subtransparent to translucent.

Composition, $3Ag_2S.\ As_2S_3$; sometimes contains a small percentage of antimony.

§ 4.—COLOUR AND STREAK.

By purely reflected light the colour of both minerals is the same, namely, black or grey-black; it is not until the light is partially transmitted that the colour assumes the various red tints which have been described under numerous names in the text-books; these tints vary, to a certain extent, with the thickness of the mineral, and are complicated by the tarnish. A definite name can only be applied when either mineral is examined by transmitted light in splinters or sections which are so thin

[1] Pyrargyrite is a little harder than Proustite.

as to be translucent or sub-transparent. The colour of Pyrargyrite is then seen to be reddish-purple, and that of fresh Proustite almost vermilion-red.

The colours of the minerals seen, as is generally the case, by light which is partly transmitted and partly reflected, afford no clue to their composition; Proustite darkens by exposure into a deeper black than that of Pyrargyrite; and Pyrargyrite of a light-red colour is sometimes found to contain no arsenic. The light colour of some Pyrargyrites is due sometimes to tarnish and sometimes to the drusy character of the mineral; a number of minute crystals transmitting enough light to yield almost the superficial colour of Proustite. It is only when sufficiently thin splinters are examined that the Pyrargyrite is seen to have a blueness of tint which is absent from Proustite.

A perfectly safe means of distinguishing the two minerals is afforded by their streak.

This has also been described under a variety of names by different observers. If, however, the colour of the streak be always determined by detaching a minute fragment of the mineral and crushing it upon white paper with the blade of a knife, it will be found that only two colours are obtained from the Red Silvers; one which is purplish-red is the streak of Pyrargyrite, the other which is scarlet-vermilion is the streak of Proustite.

All the specimens in the Museum collection were examined in this way, and separated into two groups provisionally classed as Pyrargyrite and Proustite; this necessitated the removal to the Pyrargyrites of several specimens previously called Proustite; the whole of the Pyrargyrite specimens were then tested for arsenic, and those which contained the greatest quantity of arsenic were quantitatively analysed in the hope of finding intermediate varieties. The results of these analyses are given below; in no case was more than 2·6 per cent. of arsenic found in a specimen having the darker streak.

When the streak is examined in this way from a small amount of the powder on white paper no appreciable difference can be noticed between the colour of pure Pyrargyrite and of that containing two or three per cent. of arsenic; when, however, a considerable quantity of the substance is powdered, the arsenical varieties of Pyrargyrite are seen to have a slightly lighter colour than the pure mineral.

The streak of Pyrargyrite is very nearly identical with the maroon coloured streak of kermesite, only differing from it in being less brown; the streak of unaltered Proustite is very nearly identical with that of Cinnabar, only differing from it in lacking the rose tint which is perceptible in Cinnabar, and in approaching more nearly to a brick red.

The streak of altered Proustite, or the altered streak of fresh Proustite, passes through brick-red to a brownish-black colour; but this cannot be confused with the purplish-red of Pyrargyrite. I have found it quite easy to distinguish the streaks upon paper of the two minerals after they have been exposed to daylight and direct sunlight for two years and a half.

Compared with Chevreul's scale (*Mém. Ac. Sci.* 1861, Vol. XXXIII.), the streak of Proustite is nearly rouge-orange 2, darkened $\frac{1}{10}$; that of Pyrargyrite is violet 4, darkened $\frac{3}{10}$.

Compared with the tints given in the "Nomenclature of Colors," by R. Ridgway (Boston, 1886):—

Proustite is scarlet-vermilion, Plate VII. No. 10.

Pyrargyrite is burnt carmine, Plate VII. No. 1.

Compared with Radde's Internationale Farben-skala (Hamburg, 1877) the colours are:—

Proustite; colour by transmitted light, 1 *k*; streak, 30 *k*.

Pyrargyrite; colour by transmitted light, 26 *k*; streak, 26 *f*.

An examination of the streak upon paper also serves conveniently to detect impurities which may be present in either mineral, even in very minute quantities; the black streak of stephanite or the deep "cherry-red" (maroon) of miargyrite being clearly discernible, if present, by contrast with the true Red Silver colours.

§ 5.—Habit.

The faces naturally fall into two groups, those which determine the general shape of a crystal and those which form its termination; in other words, the lateral and terminal faces.

The lateral faces are those which lie between that part of the zone *rs* which is comprised between the faces *r* and *s*, and the prism zone.

The terminal faces are those which lie between the zone *rs* and the basal plane *o*, including both. The habit of the lateral faces may be:—

(*a*). Prismatic, when the prism *a* is predominant; figs. 2-7 and 11-13; *cf* Lévy, figs. 22, 24, 30.

(*b*). Prolate, when positive scalenohedra in the zone *ar* are predominant and give the crystal a rounded appearance; fig. 1; *cf* Lévy, figs. 32, 33.

(*c*). Lanceolate, when negative scalenohedra in the zone *br* are predominant; figs. 8, 9.

(*d*). Scalenohedral, when a positive scalenohedron is predominant, fig. 10; *cf* Lévy, figs. 5, 8, 12, 26.

The habit of the terminal faces may be:—

(*a*). Pyramidal, when the predominant faces are *t*, *p* or *w*, in the case of Pyrargyrite, and *M* in the case of Proustite. Figs. 3, 5, 6, 11, 12; *cf* Lévy, figs. 4, 31, 33.

(*b*). Rhombohedral, when the predominant face is the rhombohedron *e* or *r*, fig. 4; *cf* Lévy, figs. 2, 5, 10, 12, 20.

The pyramidal habit may pass into the rhombohedral by the development of a series of striated faces in the zone *er* (Andreasberg); and the rhombohedral may pass into a flat termination approaching the basal plane by a polysynthetic development of the rhombohedra *e* or *u* (Guanaxuato); *cf* Lévy, figs. 37-39.

§ 6.—Determination of the Rhombohedron Angle.

Great care is required in selecting the measurements from which the elementary dimensions of a crystal are to be determined. For example, one of the brightest common forms in both Pyrargyrite and Proustite is the scalenohedron v, $20\bar{1}$, $R3$. The obtuse and acute angles of this scalenohedron for different values of the rhombohedron angles $rr = 100 : 010 = RR$ and $ee = 110 : 101 = -\frac{1}{2}R : -\frac{1}{2}R$, are:—

rr.	*ee.*	*vv.*		
71°13′	41°58′	35°11′	74°22′	Pyrargyrite—Rethwisch.
71°18′	42°2′	35°12′	74°24′	,, Miller.
71°22′	42°5′	35°12′	74°25′	,, Miers.
71°30′	42°12′	35°13′	74°27′	,, Phillips.
72°10′	42°44½′	35°17½′	74°38½′	Proustite—Rethwisch.
72°12′	42°46′	35°18′	74°39′	,, Miers.

It is clear from this table that any change in the dimensions makes itself far more apparent in the rhombohedron than in the scalenohedron angles, and in the acute than in the obtuse scalenohedron angle. The dimensions as calculated from a measurement of the latter may, therefore, be very inexact if the measured angle is not reliable to one minute.

The axial ratio for pure Pyrargyrite is determined by Rethwisch from the following data, which are derived from a single crystal:—

	Measured.	Limits.	Calculated from $rr = 71°22'$	Calculated from $rr = 71°13'$
vv	35°10′47″	35°12′30″—35°9′30″	35°12′	35°11′
vv	74°25′21″	74°26′ —74°24′30″	74°25′	74°22′
ev	50°21′23½″	50°22′ —50°20′30″	50°21′	50°19½′

Though not deserving much weight, as being only the measurements of three edges upon a single crystal, these results, if they show anything, indicate that here the dimensions of pure Pyrargyrite are not to be distinguished from those of the arsenical variety, and that the rhombohedron angle is 71°22′ (not 71°13′ as deduced by Rethwisch).

This is also the angle adopted for Pyrargyrite by myself; it is deduced from measurements of the angle *ee* or *rr* on 14 crystals belonging to five specimens, of which three are from Andreasberg, one from Freiberg, and one from Guanaxuato. All these specimens are free from any trace of arsenic[1]; only those crystals were selected which yielded perfectly definite images from all three rhombohedron faces, and on which the three rhombohedron angles of the same crystal did not differ by more than one minute. The result is :—

rr.	No. of Edges.	Limits of *rr*.	Limits of *ee*.
71°22′	42	71°17′—71°23′	42°1′—42°6′

Each measurement was repeated three times.

The angle of Proustite determined in the same way by the angle *ee* from 22 crystals belonging to ten specimens, of which three are from Freiberg, two from Mexico, and five from Chañarcillo, is

rr.	No. of Edges.	Limits of *rr*.	Limits of *ee*.
72°12′	66	72°8′—72°13′	42°43′—42°47′

Of these specimens one contains 1·4 per cent. of antimony, and was described in the *Mineralogical Magazine*, Vol. VII. (1888), p. 196; the rest are probably almost free from antimony.

The individual variations to which the measured angles are liable are so considerable that the above is the only safe method. Confirmatory measurements of angles which are not sensitive to variations in the elements of the crystal (like the angle *vv* = 35° 13′ above) are of little value.

For further determinations see § 22.

Irregular variations in measured angles.—When the attempt is made to determine the rhombohedron angle of a single crystal with accuracy by direct measurement, a difficulty arises from the fact that the angles which the three faces make with each other are rarely the same. Individual variations of four or five minutes are not uncommon even where the faces are perfectly smooth and bright.

For example, three very perfect crystals of Proustite from a single Chañarcillo specimen yielded the following measurements :—

[1] They were all tested for arsenic by the Fresenius-Babo method.

	I.	II.	III.
e_1e_2	42°39′50″	42°40′17″	42°43′13″
e_2e_3	42°40′3″	42°41′13″	42°43′47″
e_3e_1	42°48′27″	42°47′30″	42°44′37″
Mean	42°42′47″	42°43′0″	42°43′52″

Here the first two crystals illustrate the only regularity which can be noticed in these variations; they indicate a deviation of one of the rhombohedron faces in a vertical plane, either towards or from the summit of the crystal.

Another example in which there is less regularity is given by a crystal of Proustite from Chañarcillo on which the measured angles were :—

$$r_1r_2 = 72°1'57'' \qquad e_1e_2 = 42°44'57''$$
$$r_2r_3 = 72°10'50'' \qquad e_2e_3 = 42°46'53''$$
$$r_3r_1 = 72°5'20'' \qquad e_3e_1 = 42°46'20''$$

Here e_1 is the face truncating the edge r_2r_3, and so on in cyclical succession.

It need hardly be observed that the seconds given above are only the result of taking the arithmetic mean of several observations. The readings were estimated to ten seconds, and the errors of observation do not amount to more than twenty seconds.

These examples illustrate the necessity of deducing the parameters of a crystal of Red Silver only from the most carefully selected measurements.

§ 7.—Established Forms. (Plate VI.)

The following table gives a list of forms which are established upon sufficient evidence. The letters in the first column are those used in the list of forms first published (*Min. Mag.* VII. plate IV.), those in the second column are the letters used in Goldschmidt's Index; the column headed G_1 contains the symbols which are denoted by G_1 in the Index. (The letters used in *Min. Mag.* VII. plate IV. are retained in preference to those of Goldschmidt, since the use of German letters is very inconvenient for English readers, and the system of dots used by Goldschmidt is objectionable, since they are easily confused with a full stop following the letter. This objection does not apply to a dash used above the letter.)

The last column denotes the previous authors by whom the forms have been recorded, and is explained by the following table:—

1. Haüy. *Traité de Minéralogie.* 1822.
2. Lévy. *Description d'une Collection, &c.* 1837.

3. Mohs. *Anfangsgründe der Naturgeschichte.* 1839.
4. Hausmann. *Handbuch der Mineralogie.* 1847.
5. Miller. *Phillips's Mineralogy.* 1856.
6. Dufrénoy. *Traité de Minéralogie.* 1856.
7. Sella. *Quadro delle forme, &c.* 1856.
8. Klein. *Krystallberechnung.* 1876.
9. Groth. *Mineralien-sammlung, &c.* 1878.
10. Streng. *Neues Jahrbuch,* p. 900. 1878.
11. Max Schuster. *Zeitschr. für Kryst. XII.* 1887.

+ signifies that the form has been observed by myself. The forms marked (?) require verification before they can be accepted as absolutely certain.

Those given in § 4 are the only faces which have been definitely established with a record of the mineral (*i.e.* whether Pyrargyrite or Proustite) to which they belong; they are the only faces which can be used with safety in a discussion of the connection and distribution of forms. Those of them which occur as typical independent faces, apparently not induced by zones, are given in § 14.

After the prisms and rhombohedra and the principal zone *a r e*, the forms are arranged in descending order of the fraction $\frac{k}{-l}$, where (hkl) is the symbol of the form. Each group of faces for which this fraction is the same is indicated by a line, and represents a zone radiating from the plane (100) *R*; within each such group the forms are arranged in descending order of the fraction $\frac{h}{-l}$, *i.e.* in the order of increasing distance from the plane (100) *R*. (*cf* § 20.)

			Miller.	Naumann.	Bravais.	G_1.	Author.
? ?	*o*	*o*	111	*oR*	0001	0	All
	a	*a*	$10\bar{1}$	$\infty P2$	$11\bar{2}0$	∞	All +
	b	*b*	$2\bar{1}\bar{1}$	∞R	$10\bar{1}0$	∞ 0	All +
?	Θ	σ	17 8 $\bar{9}$	$\infty R\frac{13}{12}$	25 1 $\overline{26}$ 0	25 ∞	7
	τ	η	$3\bar{1}\bar{2}$	$\infty R\frac{5}{3}$	$41\bar{5}0$	4 ∞	7 10 +
	f′	ζ	$7\bar{2}\bar{5}$	$\infty R2$	$31\bar{4}0$	3 ∞	+
	β	θ	$5\bar{1}\bar{4}$	$\infty R3$	$21\bar{3}0$	2 ∞	7 8 9 +
?	*m*	*m*·	$3\bar{1}\bar{1}$	$4R$	$22\bar{4}3$	4 0	2 5 6 7
	T	*k*·	$4\bar{1}\bar{1}$	$\frac{5}{2}R$	$50\bar{5}2$	$\frac{5}{2}$ 0	2 6 7 10 +
	Π	*z*·	$8\bar{1}\bar{1}$	$\frac{3}{2}R$	$30\bar{3}2$	$\frac{3}{2}$ 0	+
	r	*p*·	100	R	$10\bar{1}1$	1 0	All +
	r′	*v*·	16 1 1	$\frac{5}{6}R$	$50\bar{5}6$	$\frac{5}{6}$ 0	9
?	R	*w*·	811	$\frac{7}{10}R$	7 0 $\bar{7}$ 10	$\frac{7}{10}$ 0	7
	I	*x*·	611	$\frac{5}{8}R$	$50\bar{5}8$	$\frac{5}{8}$ 0	7 +
	u	*d*·	211	$\frac{1}{4}R$	$10\bar{1}4$	$\frac{1}{4}$ 0	All +
?	*W′*	ι·	332	$-\frac{1}{8}R$	$01\bar{1}8$	$-\frac{1}{8}$ 0	7
	e	δ·	110	$-\frac{1}{2}R$	$01\bar{1}2$	$-\frac{1}{2}$ 0	All +
?	*h*	ρ·	$55\bar{4}$	$-\frac{3}{2}R$	$03\bar{3}2$	$-\frac{3}{2}$ 0	3 5 7
	s	φ·	$11\bar{1}$	$-2R$	$02\bar{2}1$	-2 0	All +
	Γ	Δ·	$33\bar{4}$	$-\frac{7}{2}R$	$07\bar{7}2$	$-\frac{7}{2}$ 0	7 +
	f	Ξ·	$22\bar{3}$	$-5R$	$05\bar{5}1$	-5 0	2 5 6 7 8 9 +
?	Λ	*h*:	540	$-\frac{1}{3}R\frac{5}{3}$	$14\bar{5}9$	$-\frac{4}{9}$ $\frac{1}{9}$	7
?	*z′*	*i*:	430	$-\frac{2}{7}R2$	$13\bar{4}7$	$-\frac{3}{7}$ $\frac{1}{7}$	7
	υ	*z*:	320	$-\frac{1}{5}R3$	$12\bar{3}5$	$-\frac{2}{5}$ $\frac{1}{5}$	7 11 +
	ω	*j*:	530	$-\frac{1}{8}R5$	$23\bar{5}8$	$-\frac{3}{8}$ $\frac{1}{4}$	11 +
	Σ	*k*:	13 7 0	$-\frac{1}{20}R13$	6 7 $\overline{13}$ 20	$-\frac{7}{20}$ $\frac{3}{10}$	7 11
	p	π	210	$\frac{2}{3}P2$	$11\bar{2}3$	$\frac{1}{3}$	2 5 6 7 9 11 +
	Π′	*o*:	13 6 0	$\frac{1}{19}R13$	7 6 $\overline{13}$ 19	$\frac{7}{19}$ $\frac{6}{19}$	+
	Γ′	*x*:	730	$\frac{1}{10}R7$	4 3 $\bar{7}$ 10	$\frac{2}{5}$ $\frac{3}{10}$	+
	Υ	*l*:	520	$\frac{1}{7}R5$	$32\bar{5}7$	$\frac{3}{7}$ $\frac{2}{7}$	7 11 Naumann
	τ′	*m*:	830	$\frac{2}{11}R4$	5 3 $\bar{8}$ 11	$\frac{5}{11}$ $\frac{3}{11}$	7 +
	λ	*v*:	11 4 0	$\frac{1}{5}R\frac{11}{3}$	7 4 $\overline{11}$ 15	$\frac{7}{15}$ $\frac{4}{15}$	vom Rath +
	t	*t*:	310	$\frac{1}{4}R3$	$21\bar{3}4$	$\frac{1}{2}$ $\frac{1}{4}$	All +
?	*e′*	*n*:	10 3 0	$\frac{4}{13}R\frac{5}{2}$	7 3 $\overline{10}$ 13	$\frac{7}{13}$ $\frac{3}{13}$	7
	θ′	*g*:	720	$\frac{1}{3}R\frac{7}{3}$	$52\bar{7}9$	$\frac{5}{9}$ $\frac{2}{9}$	+
	w	*w*:	410	$\frac{2}{5}R2$	$31\bar{4}5$	$\frac{3}{5}$ $\frac{1}{5}$	1 2 4 5 6 7 9 10 +
	φ	*e*:	510	$\frac{1}{2}R\frac{5}{3}$	$41\bar{5}6$	$\frac{2}{3}$ $\frac{1}{6}$	+
	ξ	*q*:	610	$\frac{4}{7}R\frac{3}{2}$	$51\bar{6}7$	$\frac{5}{7}$ $\frac{1}{7}$	9
	G′	*b*:	810	$\frac{3}{2}R\frac{4}{3}$	$71\bar{8}9$	$\frac{7}{9}$ $\frac{1}{9}$	+

			Miller.	Naumann.	Bravais.	G_1.	Author.
	w'	E:	$50\bar{1}$	$R\frac{3}{2}$	$51\bar{6}4$	$\frac{5}{4}\ \frac{1}{4}$	+
	n	F:	$40\bar{1}$	$R\frac{5}{3}$	$41\bar{5}3$	$\frac{4}{3}\ \frac{1}{3}$	2 7 11 +
	ψ	H:	$30\bar{1}$	$R2$	$31\bar{4}2$	$\frac{3}{2}\ \frac{1}{2}$	+
	s'	π:	$70\bar{3}$	$R\frac{5}{2}$	$7\ 3\ \overline{10}\ 4$	$\frac{7}{4}\ \frac{3}{4}$	+
	v	K:	$20\bar{1}$	$R3$	$21\bar{3}1$	$2\ 1$	All +
	ζ	ε:	$90\bar{5}$	$R\frac{7}{2}$	$9\ 5\ \overline{14}\ 4$	$\frac{9}{4}\ \frac{5}{4}$	7 11 +
	γ	N:	$50\bar{3}$	$R4$	$53\bar{8}2$	$\frac{5}{2}\ \frac{3}{2}$	7 9 10 11 +
	I'	J:	$17\ 0\ \overline{11}$	$R\frac{14}{3}$	$17\ 11\ \overline{28}\ 6$	$\frac{17}{6}\ \frac{11}{6}$	11
	y	P:	$30\bar{2}$	$R5$	$32\bar{5}1$	$3\ 2$	2 3 5 6 7 11 +
	Δ	Q:	$19\ 0\ \overline{13}$	$R\frac{16}{3}$	$19\ 13\ \overline{32}\ 6$	$\frac{19}{6}\ \frac{13}{6}$	10 11 +
?	Ω	R:	$10\ 0\ \bar{7}$	$R\frac{17}{3}$	$10\ 7\ \overline{17}\ 3$	$\frac{10}{3}\ \frac{7}{3}$	7
?	κ	ζ:	$70\bar{5}$	$R6$	$7\ 5\ \overline{12}\ 2$	$\frac{7}{2}\ \frac{5}{2}$	7
	c	T:	$40\bar{3}$	$R7$	$43\bar{7}1$	$4\ 3$	1 2 4 6 7 11 +
	Δ'	ν:	$17\ 0\ \overline{13}$	$R\frac{15}{2}$	$17\ 13\ \overline{30}\ 4$	$\frac{17}{4}\ \frac{13}{4}$	+
	π'	Z:	$90\bar{7}$	$R8$	$9\ 7\ \overline{16}\ 2$	$\frac{9}{2}\ \frac{7}{2}$	4 11
	Z	U:	$50\bar{4}$	$R9$	$54\bar{9}1$	$5\ 4$	+
	N'	κ:	$17\ 0\ \overline{15}$	$R16$	$17\ 15\ \overline{32}\ 2$	$\frac{17}{2}\ \frac{15}{2}$	+
?	c'	Π	$15\ 2\ \bar{1}$	$\frac{5}{8}R\frac{8}{5}$	$13\ 3\ \overline{16}\ 16$	$-1\ \frac{\bar{3}}{16}$	7
?	χ	Ξ	$82\bar{1}$	$\frac{1}{3}R3$	$21\bar{3}3$	$-1\ \frac{\bar{1}}{3}$	7
	a'	Γ	$72\bar{1}$	$\frac{1}{4}R4$	$53\bar{8}8$	$-1\ \frac{\bar{3}}{8}$	7 +
	Ψ	ξ:	$62\bar{1}$	$\frac{1}{7}R7$	$43\bar{7}7$	$-1\ \frac{\bar{3}}{7}$	+
	δ	$\mathfrak{t}$:	$32\bar{1}$	$-\frac{1}{2}R2$	$13\bar{4}4$	$1\ \frac{\bar{1}}{4}$	7 8 9 +
?	μ'	$\mathfrak{n}$:	$85\bar{3}$	$-\frac{1}{2}R\frac{11}{5}$	$3\ 8\ \overline{11}\ 10$	$-\frac{4}{5}\ \frac{3}{10}$	7
	ϵ	J	$20\ 11\ \bar{7}$	$-\frac{3}{8}R3$	$36\bar{9}8$	$-\frac{3}{4}\ \frac{3}{8}$	8 9
	M	L	$63\bar{2}$	$-\frac{2}{7}R4$	$35\bar{8}7$	$-\frac{5}{7}\ \frac{3}{7}$	1 7 10 +
?	η'	A:	$84\bar{3}$	$-\frac{1}{3}R\frac{11}{3}$	$4\ 7\ \overline{11}\ 9$	$-\frac{7}{9}\ \frac{4}{9}$	7
	ρ	γ:	$64\bar{3}$	$-\frac{5}{7}R\frac{9}{5}$	$27\bar{9}7$	$-1\ \frac{2}{7}$	+
	B	ψ:	$17\ 5\ \bar{4}$	$\frac{1}{6}R7$	$43\bar{7}6$	$\frac{1}{2}\ \frac{2}{3}$	+
	K	ϕ:	$21\ 6\ \bar{5}$	$\frac{2}{11}R\frac{13}{2}$	$15\ 11\ \overline{26}\ 22$	$\frac{1}{2}\ \frac{15}{22}$	+
	i	$\mathfrak{a}$:	$51\bar{1}$	$\frac{2}{5}R3$	$42\bar{6}5$	$\frac{4}{5}\ \frac{2}{5}$	5 7
	σ	$\mathfrak{b}$:	$41\bar{1}$	$\frac{1}{4}R5$	$32\bar{5}4$	$\frac{3}{4}\ \frac{1}{2}$	7 +
?	Σ'	$\mathfrak{c}$:	$52\bar{2}$	$-\frac{1}{5}R7$	$34\bar{7}5$	$-\frac{4}{5}\ \frac{3}{5}$	4 +
	d	$\mathfrak{e}$:	$21\bar{1}$	$-\frac{1}{2}R3$	$12\bar{3}2$	$-1\ \frac{1}{2}$	2 3 5 6 7 8 9 +
	π	F	$19\ 11\ \overline{12}$	$-\frac{5}{6}R\frac{31}{15}$	$8\ 23\ \overline{31}\ 18$	$-\frac{23}{18}\ \frac{4}{9}$	+
	Ξ	ρ:	$27\ 6\ \bar{7}$	$\frac{4}{13}R\frac{17}{4}$	$21\ 13\ \overline{34}\ 26$	$\frac{1}{2}\ \frac{21}{26}$	+
	S	$\mathfrak{r}$:	$86\bar{7}$	$-\frac{11}{7}R\frac{15}{11}$	$2\ 13\ \overline{15}\ 7$	$-\frac{13}{7}\ \frac{2}{7}$	+

		Miller.	Naumann.	Bravais.	G_1.	Author.
θ	θ	$97\bar{8}$	$-\frac{13}{8}R\frac{17}{13}$	$2\ 15\ \overline{17}\ 8$	$-\frac{1}{4}\ \frac{15}{8}$	+
Z'	E	$13\ 9\ \overline{11}$	$-\frac{16}{11}R\frac{3}{2}$	$4\ 20\ \overline{24}\ 11$	$-\frac{20}{11}\ \frac{4}{11}$	+
L	χ:	$19\ 4\ \bar{5}$	$\frac{1}{3}R4$	$53\bar{8}6$	$\frac{1}{2}\ \frac{5}{8}$	+
η	O	$28\ 13\ \overline{17}$	$-\frac{5}{8}R3$	$5\ 10\ \overline{15}\ 8$	$-\frac{5}{4}\ \frac{5}{8}$	8 9
A	S	$15\ 3\ \bar{4}$	$\frac{5}{14}R\frac{19}{5}$	$12\ 7\ \overline{19}\ 14$	$\frac{1}{2}\ \frac{6}{7}$	7 +
x'	τ:	$26\ 5\ \bar{7}$	$\frac{3}{8}R\frac{11}{3}$	$7\ 4\ \overline{11}\ 8$	$\frac{1}{2}\ \frac{7}{8}$	+
Φ	$\mathfrak{z}$:	$13\ 2\ \bar{3}$	$\frac{1}{2}R\frac{8}{3}$	$11\ 5\ \overline{16}\ 12$	$\frac{11}{12}\ \frac{5}{12}$	+
W	$\mathfrak{Y}$:	$92\bar{3}$	$\frac{1}{4}R6$	$7\ 5\ \overline{12}\ 8$	$\frac{7}{8}\ \frac{5}{8}$	Rethwisch
m'	A	$82\bar{3}$	$\frac{1}{7}R11$	$6\ 5\ \overline{11}\ 7$	$\frac{6}{7}\ \frac{5}{7}$	+
l	Σ	$62\bar{3}$	$-\frac{1}{5}R9$	$45\bar{9}5$	$-1\frac{4}{5}$	7 +
α	$\mathfrak{E}$:	$42\bar{3}$	$-R\frac{7}{3}$	$25\bar{7}3$	$-\frac{5}{3}\ \frac{2}{3}$	2 7 11 +
P	$\mathfrak{n}$:	$32\bar{3}$	$-2R\frac{3}{2}$	$15\bar{6}2$	$-\frac{5}{2}\ \frac{1}{2}$	10 11 +
F'	ω:	$40\ 7\ \overline{11}$	$\frac{5}{12}R\frac{17}{5}$	$11\ 6\ \overline{17}\ 12$	$\frac{1}{2}\ \frac{11}{12}$	+
? u'	$\mathfrak{S}$:	$17\ 16\ \overline{25}$	$-5R\frac{21}{20}$	$1\ 41\ \overline{42}\ 8$	$-\frac{1}{8}\ \frac{41}{8}$	7
t'	B	$18\ 4\ \bar{7}$	$\frac{1}{5}R\frac{25}{3}$	$14\ 11\ \overline{25}\ 15$	$\frac{14}{15}\ \frac{11}{15}$	+
? D'	I	$13\ 6\ \overline{11}$	$-\frac{5}{4}R\frac{12}{5}$	$7\ 17\ \overline{24}\ 8$	$-\frac{17}{8}\ \frac{7}{8}$	7
U	Θ	$91\bar{2}$	$\frac{5}{8}R\frac{11}{5}$	$8\ 3\ \overline{11}\ 8$	$1\ \frac{3}{8}$	7 +
? g	C:	$71\bar{2}$	$\frac{1}{2}R3$	$21\bar{3}2$	$1\ \frac{1}{2}$	2 5 6 7 +
P'	G	$61\bar{2}$	$\frac{2}{5}R4$	$53\bar{8}5$	$1\ \frac{3}{5}$	7 +
z	$\mathfrak{h}$:	$51\bar{2}$	$\frac{1}{4}R7$	$43\bar{7}4$	$1\ \frac{3}{4}$	5 7 +
E	$\mathfrak{p}$:	$21\bar{2}$	$-2R2$	$13\bar{4}1$	$-1\ 3$	2 6 7 +
? K'	Φ	$13\ 7\ \overline{14}$	$-\frac{5}{2}R\frac{9}{5}$	$27\bar{9}2$	$-1\ \frac{7}{2}$	6 7
F	Ψ	$9\ 5\ \overline{10}$	$-\frac{11}{4}R\frac{19}{11}$	$4\ 15\ \overline{19}\ 4$	$-1\ \frac{15}{4}$	7 +
Ω'	ε:	$74\bar{8}$	$-3R\frac{5}{3}$	$14\bar{5}1$	$-1\ 4$	+
N	V:	$53\bar{6}$	$-\frac{7}{2}R\frac{11}{7}$	$2\ 9\ \overline{11}\ 2$	$-1\ \frac{9}{2}$	7 +
H	Ω	$8\ 5\ \overline{10}$	$-4R\frac{3}{2}$	$15\bar{6}1$	$-1\ 5$	7 10 11 +
q	$\mathfrak{X}$:	$32\bar{4}$	$-5R\frac{7}{5}$	$16\bar{7}1$	$-1\ 6$	7 8 9 11 +
G	$\mathfrak{Z}$:	$43\bar{6}$	$-8R\frac{5}{4}$	$1\ 9\ \overline{10}\ 1$	$-1\ 9$	7 +
D	δ:	$54\bar{8}$	$-11R\frac{13}{11}$	$1\ 12\ \overline{13}\ 1$	$-1\ 12$	+
? B'	$\mathfrak{s}$:	$73\bar{7}$	$-2R\frac{7}{3}$	$4\ 10\ \overline{14}\ 3$	$-\frac{10}{3}\ \frac{4}{3}$	7
? o'	Δ	$12\ 2\ \bar{5}$	$\frac{1}{3}R\frac{17}{3}$	$10\ 7\ \overline{17}\ 9$	$\frac{10}{9}\ \frac{7}{9}$	7
Q	D	$15\ 1\ \bar{3}$	$\frac{10}{13}R\frac{9}{5}$	$14\ 4\ \overline{18}\ 13$	$\frac{14}{13}\ \frac{4}{13}$	+
C	C	$12\ 1\ \bar{3}$	$\frac{7}{10}R\frac{15}{7}$	$11\ 4\ \overline{15}\ 10$	$\frac{11}{10}\ \frac{2}{5}$	+
Y	$\mathfrak{w}$:	$81\bar{3}$	$\frac{1}{2}R\frac{11}{3}$	$7\ 4\ \overline{11}\ 6$	$\frac{7}{6}\ \frac{2}{3}$	7 9 +
? x	$\mathfrak{q}$:	$31\bar{3}$	$-2R3$	$24\bar{6}1$	$-4\ 2$	2 5 7
? i'	$\mathfrak{M}$:	$52\bar{6}$	$-5R\frac{11}{5}$	$3\ 8\ \overline{11}\ 1$	$-8\ 3$	7

			Miller.	Naumann.	Bravais.	G_1.	Author.
?	k'	$\mathfrak{M}$:	$62\bar{7}$	$-5R\frac{13}{5}$	$4\ 9\ \overline{13}\ 1$	$-4\ 9$	7
	V	σ:	$13\ 1\ \bar{4}$	$\frac{7}{10}R\frac{17}{7}$	$12\ 5\ \overline{17}\ 10$	$\frac{1}{9}\ \frac{6}{5}$	+
?	g'	H	$12\ 1\ \bar{4}$	$\frac{2}{3}R\frac{8}{3}$	$11\ 5\ \overline{16}\ 9$	$\frac{11}{9}\ \frac{5}{9}$	7
?	k	$\mathfrak{x}$:	$11\ 1\ \bar{4}$	$\frac{5}{8}R3$	$10\ 5\ \overline{15}\ 8$	$\frac{5}{4}\ \frac{5}{8}$	3 5 7 9
?	v'	D:	$11\ \bar{1}\ \bar{7}$	$2R3$	$42\bar{6}1$	$4\ 2$	7
?	l'	$\mathfrak{y}$:	$13\ \bar{1}\ \bar{4}$	$\frac{11}{8}R\frac{17}{11}$	$14\ 3\ \overline{17}\ 8$	$\frac{7}{4}\ \frac{3}{8}$	7
?	y'	$\mathfrak{O}$:	$15\ \bar{2}\ \bar{8}$	$\frac{11}{5}R\frac{23}{11}$	$17\ 6\ \overline{23}\ 5$	$\frac{17}{5}\ \frac{6}{5}$	7
	n'	P:	$7\bar{1}\bar{4}$	$\frac{5}{2}R\frac{11}{5}$	$8\ 3\ \overline{11}\ 2$	$4\ \frac{3}{2}$	+
?	C'	$\mathfrak{T}$:	$6\bar{1}\bar{3}$	$\frac{5}{2}R\frac{9}{5}$	$72\bar{9}2$	$1\ \frac{7}{2}$	7
	X	W:	$8\bar{3}\bar{4}$	$10R\frac{6}{5}$	$11\ 1\ \overline{12}\ 1$	$1\ 11$	6 7 8 9+
	p'	β:	$12\ \bar{5}\ \bar{6}$	$16R\frac{9}{8}$	$17\ 1\ \overline{18}\ 1$	$1\ 17$	+

§ 8.—Rejection of Uncertain Forms.

A large number (29) of the 111 forms given by Rethwisch are here rejected.

In drawing any general conclusions from the occurrence or relative frequency of certain faces, it is of the highest importance that only those which are beyond suspicion should be taken into account. The present criticism has been mainly guided by four considerations:—

(1). A form is not established *because* it is recorded by many authors, if there is any reason to suspect that these authors copied from each other.

(2). Faces which have simple indices are not to be accepted for that reason alone, for the earlier observers naturally ascribed doubtful faces to forms with simple symbols.

(3). Faces in striated zones, or zones containing vicinal faces, must be criticised with particular care, because they have often been confused with each other.

(4). The observations of certain authors are unreliable.

In accordance with consideration (1) many forms are rejected below as copied from Lévy.

(2) is exemplified by the forms *h k m x* (marked ? in the above table), and A' $\{31\bar{1}\}$, which are not to be found in the British Museum collection, and which can hardly have been seen by the earlier observers, who give only forms of common occurrence.

(3) suggests that it is unsafe to calculate indices (as is done by Reth-

wisch) from Phillips' measurements, since, as will be shown, he confused several faces in striated zones.

(4). As regards authors, Lévy has given a very large number of excellent figures in his description of the Turner collection, but on comparing the original specimens, which form part of the Ludlam collection now in the Royal School of Mines, with Lévy's descriptions, I have found that the latter are very incorrect, and that the figures often bear little resemblance to the crystals.[1] All faces resting upon Lévy's authority are here rejected.

The forms rejected and the reasons for rejection are as follows; the letters refer to *Min. Mag.* VII., Plate IV., where the positions of these faces will be found:—

b'	411	$\frac{1}{2}R$.	Recorded by Lévy.
a'	10 1 1	$\frac{3}{4}R$.	Calculated by Rethwisch from Phillips.
m	$3\bar{1}\bar{1}$	$4R$.	Recorded by Lévy.
X'	221	$-\frac{1}{5}R$.	,, ,,
ζ'	771	$-\frac{2}{5}R$.	Calculated by Rethwisch from Haüy (*vid. infra*).
Y'	$22\bar{1}$	$-R$.	Recorded by Lévy.
d'	$55\bar{9}$	$-14R$.	,, ,,
A'	$31\bar{1}$	$\frac{4}{3}P2$.	Recorded by Haüy.
λ'	$41\ 8\ \overline{25}$	$\frac{11}{4}P2$.	Hausmann; identical with the last.
μ	$13\ 4\ \bar{2}$	$\frac{1}{5}R5$.	Calculated by Rethwisch from Haüy (*vid. infra*).
ν	$16\ 4\ \bar{5}$	$\frac{1}{5}R7$.	Erroneously given by Rethwisch from Hausmann.
ν'	67 22 7	$\frac{5}{16}R2$.	Calculated by Rethwisch from Haüy (*vid. infra*).
q'	$73\bar{5}$	$-\frac{1}{4}R3$.	Recorded by Lévy.
ψ'	$41\bar{2}$	$2P2$.	Recorded by de Selle.
χ'	$73\bar{3}$	$-\frac{2}{7}R5$.	,, ,, ,,
ω'	$95\bar{9}$	$-2R\frac{9}{5}$.	,, ,, ,,
β'	$11\ \bar{4}\ \bar{4}$	$5R$.	Recorded by Zippe.
γ'	$17\ \bar{7}\ \bar{7}$	$8R$.	,, ,,
ϵ'	772	$-\frac{5}{16}R$.	,, ,,
E'	$33\bar{2}$	$-\frac{5}{4}R$.	,, ,,
ξ'	$25\ 1\ \overline{11}$	$\frac{4}{5}R3$.	,, ,,
ρ'	$8\bar{1}\bar{4}$	$2R2$.	,, ,,
ϕ'	$73\bar{9}$	$-8R2$.	,, ,,

[1] Mr. T. Davies, who had occasion in company with the late Mr. Ludlam to compare numerous specimens in this collection with Lévy's descriptions, tells me that the latter were also found to be very inaccurate in other species, notably topaz and diamond.

δ'	$11\,\bar{5}\,\bar{5}$	$16R.$	Recorded by Frenzel.
σ'	$9\bar{1}\bar{6}$	$\frac{5}{2}R3.$	,, ,,
υ'	$9\,4\,\overline{11}$	$-5R2.$	,, ,,
x	$31\bar{3}$	$-2R3.$	Recorded by Mohs.
κ	$11\,1\,\bar{4}$	$\frac{5}{8}R3.$	,, ,, (and by Groth).
h	$55\bar{4}$	$-\frac{3}{2}R.$	Recorded by Naumann.
	$59\,32\,\overline{67}$	$-3R\frac{7}{4}.$	,, ,,

Purgold (*loc. cit.*) adds 552, $-\frac{1}{4}R$ and 557, $-4R$ as uncertain forms.

§ 9.—Criticism of the Measurements of previous Authors.

Phillips.—Through the kindness of Prof. Lewis, of Cambridge, I have been able to examine a specimen in the Brooke Collection (which now forms part of the University Collection), which is either the actual specimen measured by Phillips[1] or one of precisely similar habit, and is probably from the Abendröthe mine, Andreasberg.

I have been able to verify the following among Phillips' faces:—

Phillips.	Symbol.			Measured.	Calculated.
g	Γ	$33\bar{4}$	$-\frac{7}{2}R$	$r\Gamma = 57°3'$	$57°9'$
P	r	100	R	$rr = 71°50'$	$71°22'$
l_1	L	$19\,4\,\bar{5}$	$\frac{1}{6}R8$	$LL = 31°19'$	$31°22'$
				$LV = 8°18'$	$8°18'$
l_2	x'	$26\,5\,\bar{7}$	$\frac{3}{8}R\frac{11}{3}$	$Vx' = 7°7'$	$7°13'$
l_3	V	$13\,1\,\bar{4}$	$\frac{7}{10}R\frac{17}{7}$	$VV = 26°46'$	$26°47'$
				$rV = 17°0'$	$16°59'$
i_4	y	$30\bar{2}$	$R5$	$yy = 45°31'$	$45°20'$
l_5	X	$8\bar{3}\bar{4}$	$10R\frac{6}{5}$	$XX = 8°25'$	$8°34'$
o	a	$10\bar{1}$	$\infty P2$		

The faces $b\, i_2\, i\, d_5$ of Phillips' figure are too dull for accurate measurement; i_3 consists of four faces near Y in the zone $rY\tau$, which will be discussed below (§ 19). The faces in the zone PP ($= rr$) are:—

p 210
t 310
w 410
ϕ 510

Between l_3 and l_2 there is a face of F' $(40\ 7\ \overline{11})$ $\frac{7}{36}R\frac{51}{7}$, determined

[1] *Mineralogy*, 1823, p. 292.

by the measurement $VF' = 6°19'$ (calculated $6°11'$). The measurements for l_4 are:—

$$l_4 l_4 = 38°34'$$
$$r l_4 = 40°7'$$

Lévy.—As stated above, this author's determinations are not sufficiently accurate to establish anything which is not confirmed by other observers.

Mohs.—k $\{11\ 1\ \bar{4}\}$ $\frac{5}{8}R3$ is doubtful, since it is the inverse of η $\{28\ 13\ \overline{17}\}$ $-\frac{5}{8}R3$; x $\{31\bar{3}\}$ $-2R3$, since it is the inverse of v' $\{11\ \bar{1}\ \bar{7}\}$ $2R3$; the form k is discussed below in § 15.

Hausmann.—From the fact that this author uses the same letters as Haüy, there can be little doubt that his list of forms is copied from Haüy, with the sole addition of $KG\frac{1}{8}$ $\{90\bar{7}\}$ $R8$.

Hausmann's $BC\frac{4}{11}$ $(r) = 41\ 8\ 2\bar{5} = \frac{11}{4}P2$ is then identical with Haüy's $\frac{5}{3}E\frac{5}{3}D^3B^5$ $(r) = 51\bar{3} = \frac{8}{3}P2$, the two forms being almost coincident, and Hausmann's $FA\frac{1}{4}\ GK\frac{5}{2}$ $(x) = 52\bar{2} = -\frac{1}{5}R7$ (not $16\ 4\ \bar{5} = \frac{1}{5}R7$ into which it is transformed by Rethwisch) is identical with Haüy's ${}^1E^1B^3D^2$ $(x) = 63\bar{2} = -\frac{2}{7}R4$.

Naumann.—The face h $\{55\bar{4}\}$ $-\frac{3}{2}R$ is given by Naumann[1] as occurring on Proustite; Naumann's figure, however, bears a striking resemblance to a common habit of Proustite (especially from Freiberg), in which an oscillatory combination of s $\{11\bar{1}\}$ with e $\{110\}$ may be easily confused with the face h. As there is no independent evidence for this form, it is regarded as doubtful above and marked (?).

$\{59\ 32\ \overline{67}\}$ $-3R\frac{7}{4}$[2] is rejected as improbable and unsupported by other authors. Goldschmidt suggests that the face may be $-3R\frac{16}{9}$. There can be little doubt that it is F $\{9\ 5\ \overline{10}\}$ $-\frac{11}{4}R\frac{19}{11}$, which is a common face on Andreasberg Pyrargyrite.

Sella.—All the forms derived from Sella's Quadro are here retained (but as needing confirmation); many have not been subsequently observed; there is nothing to show whether they belong to Pyrargyrite or Proustite, and since the description of these minerals contemplated by Sella was never published his measurements and other details are not accessible. Those of Sella's forms which have been confirmed are included in the tables of § 4.

Zippe and de Selle.—The forms given by these authors are rejected as obviously due to misprints and the incorrect interpretation of previous authors.

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1 *Lehrb. der Mineralogie*, 1828, p. 602, fig. 181.
2 *Lehrb. der reinen u. angewandten Krystallographie*, 1830, Vol. II. p. 312, fig. 718.

Frenzel.—These forms are uncertain for reasons given by Rethwisch (p. 109).

Rethwisch.—The form a' calculated from Phillips' measurements is uncertain, as stated above in the discussion of Phillips' data.

ν $\{16\ 4\ \bar{5}\}$ is an erroneous translation of Hausmann's $FA\frac{1}{4}\ GK\frac{5}{2}$, and should be $\{52\bar{2}\}$ $-\frac{1}{5}R7$.

In his memoir of 1792,[1] Haüy deduced the forms of Red Silver from the rhombic dodecahedron, not knowing at that date that it is a rhombohedral mineral. Among the faces which he gives are the icositetrahedron $211 = 202$, the tetrakis hexahedron $530 = \infty 0\frac{5}{3}$, and the hexakis octahedron $541 = 50\frac{5}{4}$. For these forms he gives the calculated angles to seconds, and the symbols may be easily verified from the angles. This description is corrected in the *Traité de Minéralogie* of 1801,[2] where the primitive form is correctly described; and the faces given in 1792 must of course be rejected.

Rethwisch, however, has taken Haüy's angles, and having found the rhombohedron and scalenohedra which correspond to them, namely $\{771\}$ $-\frac{4}{5}R$; $\{13\ 4\ \bar{2}\}$ $\frac{1}{5}R5$; $\{67\ 22\ 7\}$ $\frac{5}{16}R2$, has adopted these as certain forms. It is hardly surprising that, as is remarked by Rethwisch himself, the last form is not recorded elsewhere.

The crystal from Andreasberg, figured and described by vom Rath in *Pogg. Ann.* 158, p. 422 (fig. 22), has been re-examined by Rethwisch. According to vom Rath's original description there is a face λ $\{11\,.\,4\ 0\}$ $\frac{1}{5}R\frac{11}{3}$ between r $\{100\}$ R and e $\{110\}$ $-\frac{1}{2}R$. In a zone between λ and the prism a $\{10\bar{1}\}$ $\infty P2$ are two faces $\mu\nu$, to which the symbols μ $\{13\ 4\ \bar{2}\}$ $\frac{1}{5}R5$ and ν $\{16\ 4\ \bar{5}\}$ $\frac{1}{5}R7$ are ascribed by vom Rath. But the measured angles $\mu\mu = 45°23'$ and $26°49'$ are those, not of the scalenohedron $13\ 4\ \bar{2}$, but of a' $\{72\bar{1}\}$ $\frac{1}{4}R4$.

Rethwisch therefore assumes that the zone is

a	$10\bar{1}$	instead of	a	$10\bar{1}$
W	$92\bar{3}$		ν	$16\ 4\ \bar{5}$
a'	$72\bar{1}$		μ	$13\ 4\ \bar{2}$
t	310		λ	$11\ 4\ 0$

Since Rethwisch's data are not in themselves conclusive, Mr. G. Seligmann, to whom the specimen belongs, has kindly repeated the measurements with the following results :—

[1] *Journal d'Histoire Naturelle*, XVIII. p. 216.
[2] Vol. III. p. 402.

The faces between $r\ e$ belong to the form λ and not to t, the inclinations of this face to e being measured in several cases as 18°16′; 18°16½′; 18°25½′. Calculated $\lambda e = 18°32'$, $te = 19°46'$.

The occasional presence of t is, however, indicated by one measurement 19°33½′.

vom Rath's μ is	$a' = 72\bar{1}$		
Measured $\mu\mu$	26°42½′	Calculated	$a'a' = 26°46'$
	45°28′ – 46°46½′		$= 45°22'$

In the zone $\lambda\mu\nu$ the measurements are

$\lambda\mu =$ 7°31½′ – 41½′	Calculated	$ta' = 7°38\frac{1}{2}'$	$\lambda a' = 7°34\frac{1}{2}'$
$\mu\nu =$ 11°30½′ – 49′		$a'W = 11°32'$	
$\nu a =$ 40°17½′ – 24		$Wa = 40°22'$	

There can be no doubt, therefore, that $\lambda a' W$ are all well-established forms.

The forms o, m, h, x, are marked (?), although retained in the list, for the following reasons.

o never occurs as a smooth plane, but always as a drusy face composed of rhombohedral planes, or as a rough surface.

m appears to be derived from Lévy (*vid. supra*).

h is due to Naumann (*vid. supra*).

x is derived from Mohs, but is suspicious, as being the inverse of the form ν' $\{11\ \bar{1}\ \bar{7}\}$ $2R3$ given by Sella (*vid. infra* § 15), and is perhaps not supported by independent authority.

§ 10.—Measurements and Character of the Faces.

In this description the term "smooth" denotes that the form has been observed as a true plane giving a definite reflection.

a $(10\bar{1})$. Smooth; in Pyrargyrite striated parallel to $a\ v\ a\ q$; in Proustite striated parallel to τ.

b $(2\bar{1}\bar{1})$. Smooth; in Pyrargyrite striated parallel to X.

c $(40\bar{3})$. Linear; uneven; $ac = 11°15'$ (calculated 11°15′).

d $(21\bar{1})$. Smooth; always small; on Pyrargyrite with fY.

e (110). Smooth; striated parallel to e.

f $(22\bar{3})$. Somewhat uneven. $fa = 32°10'$ (calculated 32°14′).

? g $(71\bar{2})$. Linear; uneven; see §§ 15, 18.

l (62$\bar{3}$). Bright; small; on the edge *ap* (Pyrargyrite). $al = 34°55'$ (calculated 35°15').

n (40$\bar{1}$). Somewhat uneven; only at the attached end. See § 11 (6).

? *o* (111). Always drusy; never as a true plane.

p (210). Generally uneven or curved in the zone *er*; sometimes perfectly smooth in Pyrargyrite (*cf* Dufrénoy, p. 443).

q (32$\bar{4}$). Smooth; see § 11 (14).

r (100). Smooth; striated parallel to *e* in Pyrargyrite.

s (11$\bar{1}$). Smooth; striated parallel to *e* in Proustite; sometimes uneven in Pyrargyrite.

t (310). Smooth; often uneven in the zone *er*.

u (211). Uneven and rough; truncating the edge *ee*. Once observed smooth on Pyrargyrite from Joachimsthal.

v (20$\bar{1}$). Smooth; striated parallel to *a* in both minerals.

w (410). Uneven on Pyrargyrite. $ww = 15°27'$ (calculated 15°10'). Smooth on Proustite.

y (30$\bar{2}$). Smooth; sometimes large in Pyrargyrite.

z (51$\bar{2}$). Bright; small.

a' (72$\bar{1}$). Uneven; striated in zone *ra'*. $a'a' = 44°16'$ (calculated 45°22').

f' (7$\bar{2}\bar{5}$). See § 11 (1).

m' (82$\bar{3}$). Smooth; see § 11 (13) (16).

n' (7$\bar{1}\bar{4}$). Striated; see § 11 (4), Proustite.

p' (12 $\bar{5}$ $\bar{6}$). Linear; see § 11 (11) (23).

r' (16 1 1). Smooth (Groth).

s' (70$\bar{3}$). Linear; smooth. $rs' = 25°16'$ (calculated 25°13'). See § 11 (2) (8).

t' (18 4 $\bar{7}$). Smooth; see § 11 (16).

w' (50$\bar{1}$). Curved; see § 11 (6).

x' (26 5 $\bar{7}$). Linear; see § 11 (8) (13) (16).

A (15 3 $\bar{4}$). Smooth; with *FVYvet*. $eA = 31°12'$ (calculated 31°13').

B (17 5 $\bar{4}$). Smooth; see § 11 (8) (13) (20).

C (12 1 $\bar{3}$). Uneven; small; see § 11 (21).

D (54$\bar{8}$). Smooth; see § 11 (19).

E (21$\bar{2}$). Smooth; rare. (Andreasberg.) $bE = 21°39'$ (calculated 21°46').

F (9 5 $\overline{10}$). Large; slightly uneven. $FF = 22°11'$ (calculated 22°20').
92°57' (calculated 93°5').

H $(8\ 5\ \overline{10})$. Rounded towards *e*. $bH = 14°31'$ (calculated 14°16′).

I (611). Uneven; truncating the edge *ww*. (Andreasberg.) $rI = 12°41'$ (calculated 12°40′).

? *K* $(21\ 6\ \bar{5})$. Linear; see § 11 (24).

L $(19\ 4\ \bar{5})$. Smooth; see § 11 (13) (16).

M $(63\bar{2})$. Smooth and large; Proustite; forming the termination with *r v* Φ. Striated parallel to *M* and *e*. See § 11 (3), Proustite.

N $(53\bar{6})$. Uneven; linear.

P $(32\bar{3})$. Smooth in both minerals. In Pyrargyrite (Andreasberg) on the acute edge *yy*, but only as a single face. $eP = 44°20'$ (calculated $44°22\frac{1}{2}'$).

Q $(15\ 1\ \bar{8})$. Smooth; small; see § 11 (20).

S $(86\bar{7})$. Slightly uneven; linear; between $a\theta$; see § 11 (14).

T $(4\bar{1}\bar{1})$. Smooth; truncating the edge *vv*. (Bräunsdorf). $bT = 23°42'$ (calculated 23°42′).

U $(91\bar{2})$. Slightly uneven; Pyrargyrite from Andreasberg; forming the termination. $UU = 22°46'$ (calculated 22°43′).

V $(13\ 1\ \bar{4})$. Smooth. (Bräunsdorf.) See § 11 (8) (22).

X $(8\bar{3}\bar{4})$. Slightly uneven in zone bX; sometimes perfectly smooth. $XX = 8°32'$ (calculated 8°34′).

Y $(81\bar{8})$. Smooth; striated parallel to *V*.

Z $(50\bar{4})$. Smooth; see § 11 (9) (10).

F′ $(40\ 7\ \overline{11})$. Linear; see § 11 (8).

G′ (810). Linear; uneven; see § 11 (5).

I′ $(17\ 0\ \overline{11})$. Linear.

N′ $(17\ 0\ \overline{15})$. Bright, small; see § 11 (11).

Z′ $(13\ 9\ \overline{11})$. Uneven; see § 11 (14).

α $(42\bar{3})$. Smooth in both minerals; see § 11 (12); striated parallel to *e*.

β $(5\bar{1}\bar{4})$. Smooth; Pyrargyrite. $\alpha\beta = 10°47'$ (calculated $10°53\frac{1}{2}'$).

γ $(50\bar{3})$. Bright; common face.

δ $(32\bar{1})$. Smooth.

ζ $(90\bar{5})$. Uneven; curved in zone *av*, between *yv*. $a\zeta = 22°0'$ (calculated 21°41′).

θ $(97\bar{8})$. Smooth; small faces between *aa*; see § 11 (12) (14).

λ (11 4 0). Somewhat uneven in zone *er*; see § 9.

ξ (610). Striated.

π $(19\ 11\ \overline{12})$. Smooth; in oscillatory combination with *ea*; see § 11 (12).

ρ (64$\bar{3}$). Smooth; in oscillatory combination with *ea*; see § 11 (12).
σ (41$\bar{1}$). Linear; see § 11 (8).
τ (3$\bar{1}\bar{2}$). Smooth; small; see § 11 (11).
υ (320). Linear.
ϕ (510). Smooth but small; see § 11 (5) (8) (12) (20).
ψ (30$\bar{1}$). Linear; see § 11 (2) (12).
ω (530). Linear.
θ' (720). Smooth; see § 11 (1) (Proustite).
τ' (830). Linear.
π' (90$\bar{7}$). Linear.
Γ (33$\bar{4}$). Slightly curved; large, with *Fq*, &c. $r\Gamma = 57°10'$ (calculated 57°9′).
Δ (19 0 $\overline{13}$). Linear.
Ξ (27 6 $\bar{7}$). Linear; see § 11 (13).
Π (8$\bar{1}\bar{1}$). Slightly uneven; truncating edge *nn*; see § 11 (2).
Σ (13 7 0). Linear.
Φ (13 2 $\bar{3}$). Bright but uneven; see § 11 (3) Proustite. Passes into (81$\bar{2}$).
Υ (520). Smooth, small; see § 11 (13).
Ψ (62$\bar{1}$). Smooth; see § 11 (2) Proustite.
Γ' (730). Dull; see § 11 (4).
Δ' (17 0 $\overline{13}$). Linear; see § 11 (9).
Π' (13 6 0). Linear; see § 11 (2).
Ω' (74$\bar{8}$). Linear; see § 11 (18).

§ 11.—MEASUREMENTS OF NEW FORMS. (*a*). CERTAIN FORMS.

Pyrargyrite.

(1). $f' = 7\bar{2}\bar{5} = \infty R2$. Andreasberg. Two faces on an edge of the prism *a*; they are associated with *q*, which appears below them at the attached end of the crystal.

$af' = 16°10' - 16°43'$ first face.		Calculated 16°6′.
$16°14' - 17°2'$ second ,,		

(2). $\Pi = 8\bar{1}\bar{1} = \frac{3}{2}R$	$r\Pi = 12°0'$	Calculated	$11°28\frac{1}{2}'$
$s' = 70\bar{3} = R\frac{5}{2}$	$as' = 29°9'$	,,	29°6′
$\psi = 30\bar{1} = R2$	$a\psi = 34°23'$	,,	34°50′
$23\ 0\ \bar{9} = R\frac{16}{7}$	$a : 23\ 0\ \bar{9} = 31°2'$	,,	31°21′

Andreasberg: At the attached end of a crystal with $rn\gamma$; $s'\psi$ are small faces between γn,

(3.) $\Pi' = 13\ 6\ 0 = \frac{1}{19}R13$; $e\Pi' = 14°37'$ to $14°59'$; Calculated $14°50'$
Andreasberg; observed on six crystals; linear face.

(4.) $\Gamma' = 730 = \frac{1}{10}R7$, $e\Gamma' = 16°6'$ first face. Calculated $16°2'$.
$15°57'$ second face.

Andreasberg: Between ev; a small dull face.

(5.) $\phi = 510 = \frac{1}{2}R\frac{5}{3}$ $\quad r\phi = 9°58'$ $\quad$ Calculated $10°5'$
$G' = 810 = \frac{2}{3}R\frac{4}{3}$ $\quad rG' = 6°20'$ $\quad$,, $6°29'$

Andreasberg: Between rw in the zone containing $y\ r\ G'\ \phi\ w\ t$; G' a linear face.

For ϕ see also under (8), (12), (20).

(6.) $w' = 50\bar{1} = R\frac{3}{2}$ $\quad aw' = 42°12'$ $\quad$ Calculated $42°41'$
Andreasberg: With $r\ n\ q\ v\ G$ at the attached end. w' is curved towards n, giving a reflection—

$$a : ? = 48°44'$$
$$an = 50°16'$$

(7.) $\psi = 30\bar{1} = R2$. See under (2) and (12).

(8.) $s' = 70\bar{3} = R\frac{5}{2}$ $\quad rs' = 25°16'$ $\quad$ Calculated $25°13'$
$\phi = 510 = \frac{1}{2}R\frac{5}{3}$ $\quad r\phi = 10°18'$ $\quad$,, $10°5'$

Andreasberg: s' a small bright face between rv, ϕ a bright face between rt, in the zone containing $y\ \gamma\ v\ s'\ r\ \phi\ t$; with $V\ F'\ x'\ \sigma\ B$.

For s' see also under (2).

$V = 13\ 1\ \bar{4} = \frac{7}{10}R\frac{17}{7}$	$t\ V = 73°36'$	Calculated	$73°50'$
$F' = 40\ 7\ \overline{11} = \frac{5}{12}R\frac{17}{5}$	$t\ F' = 67°40'$	,,	$67°39'$
$x' = 26\ 5\ \bar{7} = \frac{3}{8}R\frac{11}{3}$	$t\ x' = 66°28'$	,,	$66°37'$
$\sigma = 41\bar{1} = \frac{1}{4}R5$	$t\ \sigma = 63°41'$	,,	$63°16'$
$B = 17\ 5\ \bar{4} = \frac{1}{6}R7$	$t\ B = 61°6'$	,,	$60°49'$

For V see (22); for x' see (13); for B see (20).

(9.) $\Delta' = 17\ 0\ \overline{13} = R\frac{15}{2}$ $\quad y\ \Delta' = 5°3'$ $\quad$ Calculated $5°2'$
$Z = 50\bar{4} = R9$ $\quad y\ Z = 6°36'$ $\quad$,, $6°46'$

Freiberg: Linear faces in the striated zone containing $y\ \Delta\ \Omega\ c\ \Delta'\ Z$, on a crystal terminated by $Y\ d\ f$.

(10.) $Z = 50\bar{4} = R9$ $\quad a\ Z = 9°12'$ $\quad$ Calculated $9°47'$
Locality unknown; Z a bright face; with $a\ v\ t\ y\ q\ e\ \beta\ \tau\ \zeta$; in the zone qq. See also under (9).

(11.) $N' = 17\ 0\ \overline{15} = R16$ $\quad a\ N' = 4°59'$ $\quad$ Calculated $4°58'$
$p' = 12\ \bar{5}\ \bar{6} = 16R\frac{9}{8}$ $\quad b\ p' = 4°34'$ $\quad$,, $4°34'$
$4°14'$

Andreasberg: N' a bright face between $a\ c$; p' a small face between $b\ X$; with $a\ b\ \tau\ p\ X\ q$, and two faces of (23 9 0).

$a : 23\ 9\ 0 = 72°30'$ Calculated $72°33\frac{1}{2}'$
$= 72°37'$
$a\ \tau = 18°56'$ or $19°13'$ Calculated $19°6\frac{1}{2}'$

(12) $\rho = \quad 64\bar{3} \quad = -\frac{5}{7}R\frac{9}{5}$ $\quad e\ \rho = 23°23'$ Calculated $23°20'$
$\pi = 19\ 11\ \overline{12} = -\frac{5}{6}R\frac{31}{15}$ $\quad e\ \pi = 31°58'$,, $31°22'$
$\theta = \quad 97\bar{8} \quad = -\frac{13}{8}R\frac{17}{13}$ $\quad \theta\ \theta = 10°49'$ and $10°50'$,, $10°50'$
$\phi = \quad 510 \quad = \frac{1}{2}R\frac{5}{3}$ $\quad e\ \phi = 25°35'$ and $25°41'$,, $25°35'$
$\psi = \quad 30\bar{1} \quad = R2$ $\quad e\ \psi = 54°41'$ and $54°51'$,, $55°10'$

Locality unknown. All bright faces with $a\ b\ e\ r\ t\ \alpha\ q$; ϕ is between $e\ r$; ρ and π are between $e\ \alpha$; θ is between $\alpha\ \alpha$.

$e\ \alpha = 39°0'$ Calculated $39°2'$
$\pi\ \pi = 23°30'$,, $23°24'$

(13.) $B = 17\ 5\ \bar{4} = \frac{1}{6}R7$ $\quad bB = 52°24'$ Calculated $52°9'$
$L = 19\ 4\ \bar{5} = \frac{1}{3}R4$ $\quad bL = 47°24'$,, $47°26'$
$x' = 26\ 5\ \bar{7} = \frac{3}{8}R\frac{11}{3}$ $\quad bx' = 46°33'$,, $46°21'$
$m' = \quad 82\bar{3} \quad = \frac{1}{7}R11$ $\quad m'm' = 41°21'$,, $41°24'$
$\Xi = 27\ 6\ \bar{7} = \frac{4}{13}R\frac{17}{4}$ $\quad b\Xi = 48°8'$,, $48°7'$

Andreasberg: With $r\ y\ X\ a\ b\ t\ w\ \phi\ G'\ p\ \Upsilon$; all bright faces, though small.

$r\Upsilon = 18°19'$ Calculated $18°34'$
$rL = 15°53'$,, $15°51'$
$LL = 31°27'$,, $31°22'$
$bm' = 46°0'$,, $46°2\frac{1}{2}'$

(14.) $S = 86\bar{7} = -\frac{11}{7}R\frac{15}{11}$ $\quad SS = 12°23'$ Calculated $12°23'$
$\theta = 97\bar{8} = -\frac{13}{8}R\frac{17}{13}$ $\quad \theta\theta = 10°52'$,, $10°50'$

Freiberg (Morgenstern mine): both bright faces between $\alpha\alpha$, with eq; θ also in zone eq.

$e\theta = 37°6'$ Calculated $37°5\frac{1}{2}'$
$eq = 56°18'$,, $56°15'$
$Z' = 13\ 9\ \overline{11} = -\frac{16}{11}R\frac{3}{2}$ $\quad Z'Z' = 15°46'$ Calculated $15°43'$
$\theta = 97\bar{8} = -\frac{13}{8}R\frac{17}{13}$ $\quad \theta\theta = 10°53'$,, $10°50'$
$13\ 5\ \bar{9} = -\frac{2}{3}R\frac{11}{3}$ $\quad (13\ 5\ \bar{9}) : \theta = 12°59'$,, $13°13'$

On the same specimen. Z' bright.

(15.) Lx'. See (8), (13).

(16.) $m' = \quad 82\bar{3} \quad = \frac{1}{7}R11$ $\quad rm' = 21°39'$ Calculated $21°24'$
$t' = 18\ 4\ \bar{7} = \frac{1}{5}R\frac{25}{3}$ $\quad rt' = 21°24'$,, $21°44'$
$et' = 34°21'$,, $34°31'$

Bräunsdorf: With $e\ r\ L\ p\ \lambda\ t\ w\ d$; on a second crystal with $a\ r\ y\ X\ V\ L\ x\ Y$:

$rm' = 21°39'$ Calculated $21°24'$
$rm' = 64°5'$ „ $64°9'$
$rL = 15°52'$ „ $15°51'$
$rL = 64°9'$ „ $64°8'$
$Lx' = 1°10'$ „ $1°5'$

See also (13).

(17.) $F' = 40\ 7\ \overline{11} = \frac{5}{12}R\frac{17}{5}$. See (8) and § 9.

(18.) $\Omega' = 74\bar{8} = -3R\frac{5}{3}$ $r\Omega' = 52°59'$ Calculated $53°3\frac{1}{2}'$

Andreasberg: Between Fq; a linear face.

(19.) $D = 54\bar{8} = -11R\frac{13}{11}$ $b\,D = 6°26'$ Calculated $6°23'$

$7\ 5\ \overline{10} = -\frac{13}{2}R\frac{17}{13}$ $b : 7\ 5\ \overline{10} = 9°57'$ „ $9°55'$

Bräunsdorf: With $e\ q\ a\ b\ H$ forming part of a curved zone $b\ q$.

$b\,H = 14°31'$ Calculated $14°16'$

(20.) $Q = 15\ 1\ \bar{3} = \frac{10}{13}R\frac{9}{5}$ $r\ Q = 10°52'$ Calculated $10°55'$

$Q\ Q = 18°27'$ „ $18°22'$

$B = 17\ 5\ \bar{4} = \frac{1}{6}R7$ $V\,B = 12°54'$ „ $13°1'$

Andreasberg: A bright face on the edge between $r\ V$, with $r\ t\ \phi\ F\ v\ y\ V\ L\ B\ X$. (Fig. 8.)

$r\,\phi = 10°7'$ Calculated $10°5'$

(21.) $C = 12\ 1\ \bar{3} = \frac{7}{10}R\frac{15}{7}$ $r\ C = 13°47'$ Calculated $13°42'$

Andreasberg: Small bright face between $r\ Y$.

$r\ Y = 20°43'$ Calculated $20°38'$
$Y\,Y = 34°34'$ „ $34°31'$

(22.) $V = 13\ 1\ \bar{4} = \frac{7}{10}R\frac{17}{7}$ $V\ V = 67°38'$ Calculated $67°34'$

$V\ V = 26°50'$ „ $26°47'$

Andreasberg: With $y\ a\ \omega\ p\ t\ w\ \phi\ G'\ x'\ X\ m'\ \Delta$ and $23\ 2\ \bar{7}$; the last a dull face between $V x'$.

$V : 23\ 2\ \bar{7} = 0°31'$ Calculated $0°39'$ See also (8).

(23.) $p' = 12\ \bar{5}\ \bar{6} = 16R\frac{9}{8}$ $bp' = 4°25'$ and $4°41'$ Calculated $4°34'$

$p'\ p' = 6°0'$ „ $5°39'$

Andreasberg: A bright face between $b\ X$. See also (11).

Proustite.

(1.) $\theta' = 720 = \frac{1}{3}R\frac{7}{3}$ $\theta'\ \theta' = 44°30'$ Calculated $44°6'$

Chili: On a fragment of a crystal with v; bright faces in zone vv.

(2.) $\Psi = 62\bar{1} = \frac{1}{7}R7$ $\Psi\ \Psi = 31°10'$ Calculated $31°6'$

$\Psi\ \Psi = 41°54'$ „ $41°54'$

Chañarcillo: Bright faces with $e\ r\ v\ w\ d\ s\ M\ a$; fig. 7.

$\Psi\ \Psi = 31°18'$

Chañarcillo: With *e v a r w d M*; two faces of Ψ between *M M*.

	$M\,M = 29°17'$	Calculated 29°15′
	$M\,M = 49°45'$	,, 49°46′
(3.) $\Phi = 13\ 2\ \bar{3} = \frac{1}{3}R\frac{8}{3}$	$\Phi\,\Phi = 26°18'$	Calculated 25°26′
	$\Phi\,\Phi = 60°12'$	,, 59°32′

Chañarcillo: With *r* M *b a v*. Φ has large and very definite faces on two crystals, as shown in fig. 12; but gives indefinite images due to the rounding of the faces towards $(81\bar{2})$, with which they sometimes almost coincide.

(4.) $n' = 7\bar{1}\bar{4} = \frac{5}{2}R\frac{11}{5}$	$n'\,n' = 29°52'$	Calculated 29°52′
	$r\,n' = 37°6'$	,, 37°20′

Markirch: Bright, but striated faces; with *e a a r*.

(*b*.)—Doubtful Forms not hitherto recorded. (Pyrargyrite.)

$K = (21\ 6\ \bar{5})$ $bK = 53°2'$ Calculated 53°5′

Andreasberg: A linear face in the zone *B V* with the faces *x′ L B*.

$(23\ 0\ \bar{9})$. See above (2).

$(23\ 9\ 0)$. ,, (11).

$(13\ 5\ \bar{9})$. ,, (14).

$(7\ 5\ \overline{10})$. ,, (19).

$(23\ 2\ \bar{7})$. ,, (22).

$(23\ 2\ \bar{1})$. See § 18. A (2).

$(20\ 2\ \bar{1})$. ,, ,,

$(17\ 2\ \bar{1})$. ,, ,,

$(13\ 2\ \bar{1})$. ,, ,,

$(61\bar{3})$. See § 19.

$(25\ 4\ \overline{12})$. ,,

$(20\ 3\ \bar{9})$. ,,

$(71\ 63\ 0)$. ,,

$(61\ 53\ 0)$. ,,

$(51\ 43\ 0)$. ,,

$(41\ 33\ 0)$. ,,

$(13\ 0\ \overline{11})$. $y : 13\ 0\ \overline{11} = 9°6'$. Calculated 8°57′

Andreasberg: Linear face between *yZ*; $yZ = 24°37'$. Calculated 24°30′.

$(13\ 0\ \bar{9})$. $a : 13\ 0\ \bar{9} = 14°8'$. Calculated $14°12\frac{1}{2}'$

Andreasberg: Linear face between *av*.

§ 12.—Faces which are Common to Proustite and Pyrargyrite.

? $o = 111$	$\beta = 5\bar{1}\bar{4}$	$\gamma = 50\bar{3}$	$\zeta = 90\bar{5}$
$u = 211$	$a = 10\bar{1}$	$\alpha = 42\bar{3}$	$\tau = 3\bar{1}\bar{2}$
$r = 100$	$p = 210$	$d = 21\bar{1}$	$\Delta = 19\ 0\ \overline{13}$
$e = 110$	$t = 310$	$b = 2\bar{1}\bar{1}$	
$s = 11\bar{1}$	$w = 410$	$y = 30\bar{2}$	
$b = 2\bar{1}\bar{1}$	$v = 20\bar{1}$	$P = 32\bar{3}$	

Faces which occur on Proustite alone.

? $h = 55\bar{4}$	$M = 63\bar{2}$	$\Phi = 13\ 2\ \bar{3}$
$n' = 7\bar{1}\bar{4}$	$\theta' = 720$	$\Psi = 62\bar{1}$

The remainder of the forms given in § 4 occur on Pyrargyrite alone.

§ 13.—Relative Frequency of the Forms.

Pyrargyrite.

On 127 specimens, of which the principal localities were :—

Harz	50
Saxony... ...	25
Mexico... ...	19
Austria, &c....	9
Hiendelaencina	6
Laasphe	5

the commonest faces were :—

$a = 10\bar{1}$	on all	specimens	= 100	per cent.
$e = 110$	,, 87	,,	= 64	,,
$q = 32\bar{4}$	,, 87	,,	= 64	,,
$b = 2\bar{1}\bar{1}$	,, 69	,,	= 54	,,
$v = 20\bar{1}$	,, 58	,,	= 45	,,
$t = 310$	,, 54	,,	= $42\frac{1}{2}$	,,
$r = 100$	,, 51	,,	= 40	,,
$p = 210$	,, 22	,,	= 17	,,
$y = 30\bar{2}$	,, 18	,,	= 14	,,
$u = 211$	,, 9	,,	= 7	,,

Proustite.

On 60 specimens, of which the principal localities were :—

Chili	20
Saxony... ...	19
Austria, &c.	8
Mexico ...	4

The commonest faces were :—

$v = 20\bar{1}$ on 47 specimens or 78 per cent.
$a = 10\bar{1}$,, 45 ,, 75 ,,
$e = 110$,, 40 ,, 67 ,,
$s = 11\bar{1}$,, 25 ,, 42 ,,
$r = 100$,, 11 ,, 18 ,,
$b = 2\bar{1}\bar{1}$,, 10 ,, 17 ,,

Other faces of frequent occurrence are :—
Pyrargyrite, $X\ Y\ \alpha\ \phi\ w\ \gamma\ F\ E\ f$.
Proustite, $M\alpha$.

Rethwisch has estimated the relative frequency of the forms for Red Silver, as Irby had previously done for calcite, by counting the number of combinations recorded by Lévy in which they recur. It will be understood from what has been said above with regard to Lévy that such an estimation is of no value.

§ 14. Typical Forms. (Plate vii.)

It is important to distinguish the typical forms which occur as bright independent faces from those which appear to be only induced by crowded zones, or which only occur as small or linear faces replacing typical edges.

Pyrargyrite.

a	$10\bar{1}$	$\infty P2$	X	$8\bar{3}\bar{4}$	$10R\frac{6}{5}$	R	811	$\frac{7}{10}R$
e	110	$-\frac{1}{2}R$	V	$13\ 1\ \bar{4}$	$\frac{7}{10}R\frac{17}{7}$	Q	$15\ 1\ \bar{3}$	$\frac{10}{13}R\frac{9}{5}$
q	$32\bar{4}$	$-5R\frac{7}{5}$	L	$19\ 4\ \bar{5}$	$\frac{1}{3}R4$	B	$17\ 5\ \bar{4}$	$\frac{1}{6}R7$
b	$2\bar{1}\bar{1}$	∞R	f	$22\bar{3}$	$-5R$	N'	$17\ 0\ \overline{15}$	$R16$
v	$20\bar{1}$	$R3$	d	$21\bar{1}$	$-\frac{1}{2}R3$	α	$42\bar{3}$	$-R\frac{7}{3}$
t	310	$\frac{1}{4}R3$	F	$9\ 5\ \overline{10}$	$-\frac{11}{4}R\frac{19}{11}$	E	$21\bar{2}$	$-2R2$
r	100	R	Γ	$33\bar{4}$	$-\frac{7}{2}R$	l	$62\bar{3}$	$-\frac{1}{5}R9$
p	210	$\frac{2}{3}P2$	U	$91\bar{2}$	$\frac{5}{8}R\frac{11}{5}$	n	$40\bar{1}$	$R\frac{5}{3}$
y	$30\bar{2}$	$R5$	D	$54\bar{8}$	$-11R\frac{13}{11}$	m'	$82\bar{3}$	$\frac{1}{7}R11$
u	211	$\frac{1}{4}R$	Y	$81\bar{3}$	$\frac{1}{2}R\frac{11}{3}$	P	$32\bar{3}$	$-2R\frac{3}{2}$
$\dot{s}$	$11\bar{1}$	$-2R$	γ	$50\bar{3}$	$R4$	T	$4\bar{1}\bar{1}$	$\frac{5}{2}R$
w	410	$\frac{2}{5}R2$	z	$51\bar{2}$	$\frac{1}{4}R7$			

Proustite.

v	$20\bar{1}$	$R3$	α	$42\bar{3}$	$-R\frac{7}{3}$
a	$10\bar{1}$	$\infty P2$	M	$63\bar{2}$	$-\frac{2}{7}R4$
e	110	$-\frac{1}{2}R$	P	$32\bar{3}$	$-2R\frac{3}{2}$
s	$11\bar{1}$	$-2R$	θ'	720	$\frac{1}{3}R\frac{7}{3}$
r	100	R	Ψ	$62\bar{1}$	$\frac{1}{7}R7$
b	$2\bar{1}\bar{1}$	∞R	Φ	$13\ 2\ \bar{3}$	$\frac{1}{2}R\frac{8}{3}$

Perhaps to the typical forms of Pyrargyrite should be added $\epsilon\delta\eta$ (Klein), $a'W$ (Rethwisch and Seligmann).

§ 15.—Rhombohedral Character of the Red Silvers.

The strictly rhombohedral (as contrasted with hexagonal) character of these minerals is very striking. On Pyrargyrite or Proustite there is not a single well-attested case of the occurrence as a *typical* face of any form of which the inverse form exists (*i.e.* of $+mRn$ and $-mRn$).

The only recorded instances, with their authors, are given in the following table:—

r	100	R	Common	Y'	$22\bar{1}$	$-R$	Lévy
e	110	$-\frac{1}{2}R$	Common	b'	411	$\frac{1}{2}R$	Lévy
d	$21\bar{1}$	$-\frac{1}{2}R3$	Certain	g	$71\bar{2}$	$\frac{1}{2}R3$	Lévy
η	$28\ 13\ \overline{17}$	$-\frac{5}{8}R3$	Klein	k	$11\ 1\ \bar{4}$	$\frac{5}{8}R3$	Mohs, Groth
q'	$73\bar{5}$	$-\frac{4}{5}R3$	Lévy	ξ'	$25\ 1\ \overline{11}$	$\frac{4}{5}R3$	Zippe
C'	$6\bar{1}\bar{3}$	$\frac{5}{2}R\frac{9}{5}$	Sella	K'	$13\ 7\ \overline{14}$	$-\frac{5}{2}R\frac{9}{5}$	Sella
v'	$11\ \bar{1}\ \bar{7}$	$2R3$	Sella	x	$31\bar{3}$	$-2R3$	Mohs
E	$21\bar{2}$	$-2R2$	Common	ρ	$8\bar{1}\bar{4}$	$2R2$	Zippe

Here all the forms contained in the right hand column are doubtful for reasons given above, with the exception of $g\,k$ and K'; while on the left hand q' is uncertain as well as its inverse ξ'.

k, if supported by the authority of Mohs alone, could not be regarded as a certain form, but it is also given by Groth (*Mineralien-Sammlung der Universität Strassburg*, p. 64) as occurring on Pyrargyrite from Freiberg. The use of the letter η instead of k in Groth's description shows, however, that there has been some confusion between $\frac{5}{8}R3$ and $-\frac{5}{8}R3$, and Prof. Bücking tells me that the form is not to be found on crystals in the Strassburg collection.[1]

K', in spite of Sella's authority, may well be regarded as a doubtful form, since it lies in a curved or striated zone. There only remains the face g, from which images have been obtained in the zone $B\,V$; but this fact is not enough to establish the form with certainty.

The only form of hexagonal type which occurs on the minerals is $p=210=\frac{4}{3}P2$, which, being a deutero-pyramid, is its own inverse; and even this face, though it sometimes occurs as a bright smooth plane, is more generally replaced by two neighbouring faces (compare table § 18).

[1] Prof. Groth has subsequently informed me that this face was not observed by him, and that in line 9, p. 64, $\eta=\frac{5}{8}R3$ should be $\eta=-\frac{5}{8}R3$ (which is near to $y=\frac{1}{2}R\frac{11}{3}$ if the sign be disregarded).

The striking dissimilarity between the + and − forms is well shown by the principal zones; the rich zone of faces between *a r* is only represented on the negative side by the form *α*, which is not the inverse of any of them; the series between *b E* is only represented on the positive side by the two faces *p′X*; the series between *V B* is only represented on the negative side by the faces *t d P*.

In calcite, according to the list of forms accepted as certain by Goldschmidt, there are 22 forms which occur on both the positive and negative sides, namely 6 rhombohedra, 9 deutero-pyramids $mP2$, and the 7 scalenohedra $\pm R\frac{5}{3}$, $\pm R\frac{7}{3}$, $\pm R\frac{9}{5}$, $\pm R2$, $\pm R3$, $\pm R5$, $\pm 2R3$. It is noteworthy that $\pm 2R3$ has been also given for Red Silver.

It seems possible, then, to lay it down as a general law for Pyrargyrite and Proustite that no forms occur as *typical* faces in both the direct and inverse positions.

It may perhaps be true that no forms whatever can occur in both positions.

§ 16. Hemimorphism.

(1). Proustite. The only evidence of hemimorphism is the hemihedral development of the prisms $b=2\bar{1}\bar{1}$ upon alternate edges of $a=10\bar{1}$, and $\tau=3\bar{1}\bar{2}$ upon the remaining edges (as described by Streng, *Neues Jahrb.* 1878, p. 908). The crystals are never doubly terminated, and no definite faces can be found at the attached ends.

(2). Pyrargyrite. In the British Museum collection the following direct evidence has been obtained from 124 specimens on which the forms could be determined with certainty by inspection or measurement.

(i.) 52 specimens having indications of faces at both ends were found; of these

36 have *q* or *q b* at the attached end, with some of the forms *t e v y s f′u p r o T w φ Y l d* at the unattached end.

8 have *q* with some of the forms *a r n G v u s′ w′* at the attached end, and some of the forms *t v I y e p r u* at the unattached end.

8 show the following combinations:—

Attached End.				Unattached End.
r	...	...	...	*v y q f p t I*
r n	...	...	...	*e*
n ...	...	...	...	*v t y r g* (?)
n Π *v*	...	...	...	*β q v t* (?)
n α	...	...	...	*p*
r n Π *s′*		...	...	*F y q X V L r t e φ B x′ σ g p γ Q p′*
r α n	...	...	...	*v p*
t v Y (?)		...	...	*t v y*

3 show the following combinations:—

(*a*). $e\ r\ q$ (?) at the attached end
$q\ \alpha\ \theta\ S\ e\ Z'$ at the unattached end.

(*b*). $e\ r$ at one end
$e\ r\ t\ \psi\ \phi\ a\ \theta\ \rho\ \pi\ q$ at the other end
} An isolated crystal

(*c*). q at one end
$q\ r\ e\ v$ at the other end

(ii.) 40 specimens were found developed at one end alone, having the form q associated with faces of the forms $r\ e\ p\ w\ Y\ E\ C\ v\ y\ P\ s\ u\ f\ X\ L\ y\ \dot{\tau}\ c\ \Gamma\ F\ V\ \theta\ D\ H\ \gamma\ \alpha\ x'\ Z\ \beta\ \zeta$.

(iii.) 32 specimens were terminated at one end alone without indications of the form q, exhibiting combinations of the forms $e\ \upsilon\ p\ t\ v\ \omega\ f\ y\ r\ \gamma\ U\ X\ I\ V\ F\ s\ w\ Y\ T\ d\ L\ x'\ m'\ A$.

It must be remembered that in the above analysis the two ends have been distinguished, not always upon a single crystal, but by a careful examination of the whole specimen. One of two conclusions must be drawn from these observations, either (1) the attached ends are different from the unattached in consequence of the different conditions prevailing at the two ends, and $n\ \Pi\ \alpha\ s'$ are characteristic of the former, or (2) the two ends are essentially distinct (one being characterised by the face q), but the crystals are not always attached by the same end.

The first conclusion is supported by the fact that $n\ \Pi$ have never been found at the unattached end, and s' only once, so that these forms seem in any case to be characteristic of the attached part of the crystal; on the other hand, the mode of development of q tends strongly to confirm the second conclusion.

q generally occurs as a linear or very small face, which constitutes little more than a series of striations upon the prism a $\{10\bar{1}\}$ (fig. 13). Now these striations invariably (except where complicated by twinning) tend towards q faces at one end of the crystal alone, as has been exemplified in certain cases by Max Schuster, whose conclusions on this matter are identical with those to which I had been led, upon the very same grounds, before the publication of his paper.

The end towards which the q striations tend is generally the attached, but in Mexican and some other specimens it is the unattached end.

These facts prove that the two ends of a Pyrargyrite crystal are to be distinguished, and warrant the following classification:—

One end, which is generally characterised by the forms q, bears the forms

n	$40\bar{1}$	α	$42\bar{3}$	G	$43\bar{6}$
Π	$8\bar{1}\bar{1}$	s'	$70\bar{3}$	w'	$50\bar{1}$

and in all probability also

θ	$97\bar{8}$	π	$19\ 11\ \overline{12}$	P	$32\bar{3}$	f	$22\bar{3}$
Y	$81\bar{3}$	ρ	$64\bar{3}$	C	$12\ 1\ \bar{3}$		
S	$86\bar{7}$	ϕ	510	u	211		
Z'	$13\ 9\ \overline{11}$	D	$54\bar{8}$	r	100		
ψ	$30\bar{1}$	H	$8\ 5\ \overline{10}$	Z	$50\bar{4}$		

This end is generally attached; the faces $n\ \Pi\ s'$ are characteristic of the attached end.

It is not quite certain to which end m' and the group of faces included between VB are to be referred.[1]

The other end shows the remaining forms which have been observed on Pyrargyrite. The prism faces $\beta\ \tau$ belong to the edges of a which are not truncated, f' to those which are truncated by b and are accompanied by q.

The forms $e\ u\ p\ t\ w\ r\ v$, and perhaps Y, may occur at either end; and q may also appear at what is usually the unattached end (*cf.* fig. 9). This face, however, never appears at both ends simultaneously, the two instances given above under (a) and (c) being perhaps due to twinning. Figures 3-6 represent four crystals from Andreasberg which show a hemimorphic development, and fig. 1 represents an ideal combination of the principal forms characteristic of the two ends.

Max Schuster's observations on Pyrargyrite from Andreasberg indicate that $e\ y\ t\ v\ p\ v\ \Upsilon\ \omega$ are characteristic of one end, and $q\ n\ P\ H\ a\ w'$ of the other; it will be observed that the present results are in complete accordance with this. His statement that one end is characterised by acute positive and obtuse negative scalenohedra, while the other is characterised by obtuse positive and acute negative scalenohedra, requires modification; it is approximately true so far as the acute scalenohedra alone are concerned.

Attempts have been made in the course of the present investigation to detect pyro-electric properties in either Pyargyrite or Proustite by means of Thomson's Quadrant Electrometer; but it has hitherto been impossible to prove a difference of potential at the two ends during change of temperature in the crystals examined.

It is to be observed, however, that such properties might be entirely obscured by the twinning, at least in the case of Pyrargyrite.

We have also attempted to find evidence of hemimorphism by etching crystals with nitric acid, with a mixture of nitric and tartaric acids, and with bromine; but hitherto without any definite result.

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[1] Fig. 2 suggests that the zone b_1VBe_3 must belong to what is generally the unattached end.

§ 17. Twin-growth.

Instances of the following five twin-laws have been found in the course of the present study of tho two minerals :—

Pyrargyrite	(1.)	Twin-face *u*.
	(2.)	Twin-face *r*.
	(3.)	Twin-face *a*.
	(5.)	Twin-face *e*.
Proustite	(1.)	Twin-face *u*.
	(2.)	Twin-face *r*.
	(4.)	Twin-face *o*.
	(5.)	Twin-face *e*.

In Pyrargyrite the third law is the most common; not only almost every specimen, but almost every crystal shows indications of its operation; the first law is also very common, and is represented on most specimens; but the second and fifth are rare.

In Proustite, on the other hand, the first and second laws are both common, and the remaining two are rare.

(1.) Twin-face $u = 211 = \frac{1}{4}R$.

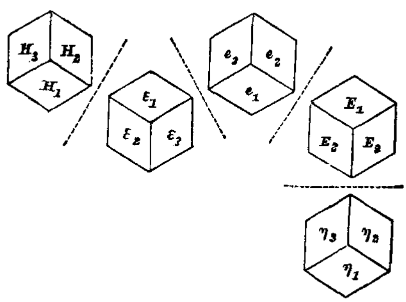
This twin-growth was admirably described by Haidinger, and illustrated by figures which have subsequently fonnd their way into all the text books.

The crystals are so grouped that a pair of faces of e $\{110\}$ $-\frac{1}{2}R$ in one individual are parallel to a pair of faces of the same form in the other (fig. 24). One large crystal generally has a number of smaller ones protruding from it, all the three faces of the form u acting as twin-planes. The unattached ends of the crystals usually make an angle of 26° with each other (*i.e.* the angle between the morphological axes is 25° 40′ in Pyrargyrite and 26°8′ in Proustite); in this case the plane of composition is in the common phraseology said to be perpendicular to the twin-plane (fig. 24); the less frequent combination, in which the unattached ends make an obtuse angle of 154°, would then be said to have the plane of composition parallel to the twin-plane (fig. 25). Both these modes of composition occur, but the former is by far the more frequent.

Since, however, there is no true plane of composition, but the crystals interpenetrate irregularly, they may be better described as developed on one side of the twin-plane in the former case, and on opposite sides of the twin-plane in the latter.

Composition perpendicular to the plane of twinning being difficult to understand, it might be suggested that these crystals are in reality twinned upon a face of the form f $\{22\bar{3}\}$ $-5R$, which is nearly perpendicular to the face u or to the edge of the rhombohedron e. If this is the case then the adjacent faces of e, which would be parallel in the two individuals on the first hypothesis, must in reality form a re-entrant angle of $51\frac{1}{2}'$ in Pyrargyrite, and of $1°41\frac{1}{2}'$ in Proustite.

To decide this point a number of twin-crystals were measured, with the result that adjacent faces of the form e upon the two individuals were found to be rarely, if ever, strictly parallel; they form an angle which is generally re-entrant, sometimes salient, and has various values from $\frac{1}{2}°$ to 9°.



This variability in the position of twin-crystals is well illustrated by a group of Pyrargyrite from Andreasberg, in which the relative positions of five crystals could be determined and are represented in the adjacent figure. This group also illustrates the variability of the rhombohedron angle upon a single specimen, and the consequent difficulty of determining its precise magnitude. The faces of $\{110\} = -\frac{1}{2} R$ are denoted by the letters e E ε η H on the five crystals respectively. The reflections were good, but not perfect.

	Twin Angle.	Rhombohedron Angle.	Mean.
(*a.*)	$e_1E_2 = 2° 13'$	$e_1e_2 = 41° 58'$	
	$e_2E_1 = 1\ 54$	$e_2e_3 = 41\ 57$	$ee = 41° 58'$
(*b.*)	$e_1\varepsilon_3 = 2\ 6$	$e_3e_1 = 42\ 0$	
	$e_3\varepsilon_1 = 4\ 13$	$E_1E_2 = 42\ 7$	
(*c.*)	$E_3\eta_2 = 0\ 55$	$E_2E_3 = 42\ 5$	$EE = 42\ 5$
(*d.*)	$\varepsilon_2H_1 = 0\ 24$	$E_3E_1 = 42\ 2$	
		$\varepsilon_1\varepsilon_2 = 42\ 2$	
		$\varepsilon_2\varepsilon_3 = 42\ 1$	$\varepsilon\varepsilon = 42\ 0$
		$\varepsilon_3\varepsilon_1 = 41\ 58$	
		$\eta_3\eta_2 = 42\ 9$	$\eta\eta = 42\ 9$
		$H_2H_1 = 42\ 7$	$HH = 42\ 7$

Other instances, in which the measurements are more accurate than the above, and are certainly reliable to one or two minutes, are as follows:—

Pyrargyrite.		Proustite.	
Twin Angles.	Rhombohedron Angles.	Twin Angles.	Rhombohedron Angles.
(1.) $e_1E_2 = 2^\circ\ 10'$	$ee = 42^\circ\ 6'$	(1.) $e_1E_2 = 0^\circ\ 57'$	$ee = 42^\circ\ 46'$
$e_2E_1 = 2\ 24$	$EE = 42\ 5$	$e_2E_1 = 0\ 56$	$EE = 42\ 46$
(2.) $e_1E_2 = 1\ 3$	$ee = 42\ 5$	(2.) $e_1E_2 = 2\ 29$	$ee = 42\ 46$
$e_2E_1 = 1\ 4$	$EE = 42\ 5$	$2\ 0$	$EE = 42\ 46$
(3.) $e_1E_2 = 1\ 33$	$ee = 42\ 6$		
$e_2E_1 = 1\ 34$	$EE = 42\ 6$		

It will be seen that these angles do not show whether u or f is the twin-plane, but they suggest the further question whether there may not be some regularity in the deviation of the crystals from the true twin position; a similar deviation in other minerals has been pointed out,[1] but has not been accurately described.

In the case of both Pyrargyrite and Proustite the angle eE upon one side of the edge common to the two crystals is usually equal to that on the other. This may take place in two ways: either (a) the zone e_1E_2 is nearly parallel to the zones ee and EE, in other words the edges ee and EE are nearly parallel, and one crystal may be regarded as having deviated from the true twin position by a rotation about the rhombohedron edge which is common to the two individuals; or (b) the zone e_1E_2 is nearly perpendicular to the rhombohedron edge ee and EE, in other words the planes a are nearly parallel, and one crystal may be regarded as having deviated from the true twin position by a rotation in the prism face a which is common to the two individuals.

If the true twin position and the deviations are to be included in a single statement, the twin-growth may be described by saying that two crystals are so united that they have in common a face $a = (10\bar{1})$, and also the edge (zone-axis) $[1\bar{1}1]$ lying in this face; their deviations from this position are due either to a slight inclination of the two faces alone, or to a slight inclination of the two edges alone.[2]

In the same way the twin-growth of Bournonite (twin-face 110) may be expressed by the statement that two crystals have a face (110) in common, and also the edge (zone-axis) [001], *i.e.* the vertical axis, lying in this face. The variations from the true twin position (described in

[1] *cf.* Des Cloizeaux, *Manuel de Minéralogie*, II. p. 109.

[2] *cf.* Max Schuster, *loc. cit.*

Min. Mag. VI. 1884, p. 77, under the heading *Irregular Conjunction*) may then be described as due to an inclination of either the face (110) or the edge [001] alone.

In the Red Silvers, when the deviation cannot be expressed either by a simple rotation about the edge *ee* or the normal to the plane *a*, the angle e_1E_2 between one adjacent pair of faces is often exactly double of that between the other pair e_2E_1 (*cf.* example (*b*) above).

No other observations seem to have been made upon the variability of twin-crystals, so that it is not possible to say whether the features here described are also to be found in other minerals.

Twin-lamellation.—Although the direct measurement of twin-crystals does not decide the question whether *u* or *f* is to be regarded as twin-plane, the fact that composition sometimes takes place parallel to the face *u* removes any objection that might be raised to the former interpretation.

The most pronounced mode of such composition is the twin-lamellation parallel to the faces *u*, which is a very common feature in Pyrargyrite, and one which has not been hitherto described. Many crystals of Pyrargyrite, if carefully examined, are found to have isolated lines of extreme fineness which run across the prism and scalenohedron faces, generally near the summit of the crystal. These lines may sometimes be traced completely round the crystal as a set of three markings parallel to the three faces of the rhombohedron *u*; they sometimes yield faint reflections on the goniometer, which indicate either (1) a face inclined at about 22° to the prism faces, or (2) a face parallel to *u*; the angle 22° is that between the prism faces of a pair of crystals twinned on *u*.

There can be no doubt, therefore, that these lines indicate fine twin-lamellæ parallel to the faces of *u*, and that they are bounded at their edges by the prism *a*, and on their surface by the face *u*, which is otherwise an extremely rare form.[2]

The lamellæ may be traced through the whole mass of a crystal as fine lines traversing the fractured surfaces, but the crystals do not seem to have any tendency to separate along the planes of lamellation. Sometimes they have more the appearance of sliding planes.

Secondary Twinning.—The face *u* has certainly in some instances played the part of a sliding plane. A crystal of Pyrargyrite from Andreasberg shows this very clearly; the crystal has evidently been crushed either during or subsequently to the process of crystallisation, and is now tra-

[1] Conclusive evidence will be found below.

[2] These lamellæ may have given rise to the statement that the prism faces are striated parallel to the face *g*. (Rethwisch, *loc. cit.* p. 80.)

versed by a series of twin-lamellæ which are distinctly visible as such, and on which the faces of the prism *a* are of sufficient breadth to give definite reflections; a good measurement is in this case possible and shows the angle between the surfaces of alternate lamellæ to be 22°8′; the calculated value is 22°11′.

Attempts to produce this twinning artificially in crystals of Pyrargyrite have not met with success. (One method adopted to obtain a uniform homogeneous pressure was to immerse a crystal in water in a closed glass tube which was placed in a freezing mixture.)

Lamellar twinning parallel to *u* has not been found in Proustite.

Connection between twin-growth and hemimorphism.—So far as the positions of the two crystals of Proustite are concerned, the twin-growth may be equally well expressed by either of the statements—

(1.) Twin-axis normal to the face *u*.

(2.) Twin-axis parallel to the edge *ee*.

But by taking into account the hemimorphic character of Pyrargyrite, we have a criterion by which the two explanations may be perfectly distinguished, at least for that mineral.

Fig. 14 represents a crystal (*ae*) of Pyrargyrite in the normal position, *q* denoting the end towards which the striations on the prism faces *a* converge to form the scalenohedron *q* (as shown in fig. 5).

A semi-rotation about the normal to *u* as twin-axis brings the crystal into the position of fig. 20, while a semi-rotation about the edge *qr* brings it into the position of fig. 21.

Fig. 22 represents the intergrowth of the crystals in the first case, fig. 23 their intergrowth on the second supposition.

If, then, (1) is the true geometrical expression of the twinning, *q* is at those ends of the crystals which make an acute angle with one another, and the twin is symmetrical about a plane which is perpendicular to the edge *qr*; if (2) is the true geometrical expression, *q* is at those ends which are inclined at an obtuse angle, and the twin is symmetrical about a plane parallel to *u*.

Now a careful examination of these twins has shown that, *except where complicated by the occurrence of the third twin-law*, the growth is always that represented in fig. 22, and the statement, "Twin-axis normal to the face *u* {211}," is a true geometrical description of the twin-growth.

As regards the mode of composition under this law, the crystals may either be developed on both sides of the twin-plane, as in fig. 25, or on one side of the twin-plane, as in fig. 24; but the latter is by far the more frequent mode of growth.

The unattached ends of a twin-crystal, such as is shown in fig. 24, may either be those which bear indications of the q faces, or those which do not.

2. Twin-face $r = 100 = R$.

This law is far more common in Proustite than Pyrargyrite, and the same considerations may be applied as in the case of the first law, the only difference being that the individuals are now nearly at right angles to one another.

A composition similar to that of fig. 22 would result from a semi-rotation about the normal to r, and a composition similar to that of fig. 23 from a semi-rotation about the edge ss lying in the face r.

An examination of the few Pyrargyrite crystals which are twinned according to this law leaves no doubt that the former alone represents the twins which occur in nature, and that they may be geometrically described by the expression

Twin-axis perpendicular to the face r; or twin-plane r (100).

In the case of Proustite there is nothing to distinguish this from hemitropy about the edge ss lying in the face r.

The twins of Proustite from Chañarcillo are described and figured by Streng as having their morphological axes inclined at an angle of 94°18′, in other words as lying upon opposite sides of the twin-plane. In all the specimens which I have been able to examine the two individuals lie upon one side of the twin-plane alone, so that their axes make an angle of 85°42′. The two cases are easily distinguished; in the former the acute edges (s) of the predominant scalenohedron v would face one another in the twin crystal, whereas in the latter the obtuse edges are always opposed, as is shown in fig. 27.

In Proustite the two first twin-laws are often combined, the angle between the two individuals of a twin on r being occupied by a third crystal twinned with one of them on u (fig. 27).

Lamellar-twinning is very rare (or perhaps does not exist) in Pyrargyrite, but is to be found, though seldom, in Proustite from various localities (*cf.* Streng).

3. Twin-face $a = 10\bar{1} = \infty P2$.

The crystals which are twinned according to this law were formerly described as twinned about the basal plane, and the figures in which the twinning is indicated by the interrupted development of the prism b $\{2\bar{1}\bar{1}\}$ ∞R at alternate ends on consecutive edges of the prism a $\{10\bar{1}\}$ $\infty P2$ are familiar in all the text books. The true explanation and significance of certain twins from Andreasberg belonging to this type were recently pointed out by Max Schuster, and his conclusions are fully confirmed by the present study of the British Museum Collection, which had led independently to precisely the same results.

Figures 14 to 19 were, in fact, drawn before the appearance of Max Schuster's paper, and may still serve to illustrate the nature of these growths. Max Schuster himself[1] appeared to regard the law as of rare and exceptional occurrence, and did not deny the existence of crystals twinned upon the basal plane or upon the prism b $\{2\bar{1}\bar{1}\}$ ∞R. According to my own observations this law is extremely common, though not conspicuous, and all cases explained by twinning upon the basal plane or b are in reality to be ascribed to twinning upon the prism a.

Starting with the crystal in the normal position of fig. 14, and distinguishing the end of the crystal towards which the oblique striations on the prism tend to form the face q $\{32\bar{4}\}$ by the letter q:

(1) a semi-rotation about the vertical axis (normal to the basal plane 111) brings it into the position of fig. 15; a composition of the two crystals in this position parallel to the basal plane would, it is true, bring the trigonal prism b (which occurs on the same edges of the prism a with the q faces) alternately to the upper and lower end of the crystal, but the form q, as indicated by the oblique striations, would appear at one end of the crystal alone.

(2) A semi-rotation about the edge between a and the basal plane (normal to the prism b) brings the crystal into the position of fig. 16; composition parallel to the basal plane would now result in a twin having the q faces symmetrically disposed at the upper and lower end, and the prism b associated with them would only appear as a trigonal prism on alternate edges of the compound crystal.

(3) A semi-rotation about the edge between the prism b and the basal plane (normal to the prism a) brings the crystal into the position of fig. 17. Composition parallel to the basal plane now results in fig. 18, if the q ends of the crystal are turned outwards, and in fig. 19 if the q ends are turned inwards. This composition is described as new by Schuster, but it had been previously figured by Naumann and described as a "Zwillingsartige Verwachsung." (See above, § 1.)

According to my own observations, the last of the three is the only case which occurs in Nature, so that all twins of Pyrargyrite having parallel axes are referable to the law

Twin-plane a $\{10\bar{1}\}$ $\infty P2$.

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[1] *Loc. cit.* p. 131.

The twin-crystal may either have its *q* ends turned outwards or inwards.

It is a peculiarity of this mode of twinning that the compound crystal has the appearance of a simple holohedral individual, unless it bears faces along the line of composition belonging to that end of the crystals which is turned inwards ; otherwise the twin-crystal must have similar terminations and the hemimorphic character is masked (see § 16).

In Pyrargyrite indications of the two distinct ends are supplied by the *q* striations, by the development of the prism *b*, or by the faces mentioned above as associated with the form *q*.

It is possible, therefore, that the same mode of twinning may occur in other rhombohedral minerals,[1] but may not be detected owing to the want of such indications, and may itself conceal their hemimorphic character. The specimens of Tourmaline in the British Museum have been searched without success; it has, however, been shown by Prof. Kundt, by the method of dusting,[2] that in a section of Tourmaline cut perpendicular to the axis there are parts which have the analogous pole above, and other parts which have it below, so that this may possibly be an example of twinning similar to that of Pyrargyrite.

In the Pyrargyrite twins the union of the two individuals never takes place parallel to the basal plane as shown in figs. 18, 19, but either (1) irregularly, (2) parallel to *u*, (3) parallel to *r*, or (4) parallel to the prism *a* ; the component crystals may also interpenetrate in every conceivable way.

Sometimes the interpenetration is so regular that each face of the prism *a* is divided into two halves by a vertical twin junction, as shown in fig. 26. In this case the crystal can only be distinguished from a simple holohedral crystal by very careful observation.

Sometimes one individual forms a shell partly surrounding the other.

The striations indicated in figs. 14 to 26 are formed by thin plates parallel to the prism *a* which overlie the prism faces ; these are bounded on their edges at one end by the faces *q n* or *q v*, and since they often lie in inverted or twin position upon a central crystal, they make it extremely difficult to determine which end of the latter is in reality the end characterised by the form *q*.

One of these twin-lamellæ as observed upon a crystal from Mexico is shown in fig. 13. Now a cursory examination of such a crystal would lead to the conclusion that the upper end of the crystal is that to which

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[1] *cf.* Schuster, p. 132.

[2] *Ber. Akad. Berlin*, 1883, p. 421.

q belongs, and that it is associated with the faces *r p*; whereas in reality *r p* belong to one end of the crystal and *a v q* to the other, which is only developed upon the twin-lamella; this is also indicated in the figure by the striations on the main crystal, which converge to *q* faces at the lower end.

The striation parallel to the face *q* is often due to this twin-lamellation; consequently, if great care is not observed in interpreting the striæ, they may lead to a completely erroneous orientation of the crystals. The striations upon the prism faces *a*, due to twinning, run parallel to the faces *a v q a*. The same cause produces a very fine twin-lamellation parallel to the prism edges, which may sometimes be observed as a vertical series of fine lines somewhat similar to those parallel to *u* which have been described under the first law.

The third law might, so far as can be seen, operate conjointly with either of the first two; it has not, however, been found in conjunction with the second. Crystals twinned according to the first law upon the face *u* are frequently complicated by the third law (as was mentioned above), each individual being a composite and apparently holohedral crystal, so that it is impossible to orientate either individual. A precisely similar difficulty is experienced in explaining twinned crystals of quartz with inclined axes, and deciding whether they are to be described as due to hemitropy about a face (*e.g.* $52\bar{1}$) or the edge lying in that face, since each individual is a composite crystal.

In Pyrargyrite, however, wherever the growth is not complicated by the third law the twin is explicable by hemitropy about the face *u*.

(4). Twin-plane $o = 111 = 0R$.

This mode of twinning is only exemplified in the Museum Collection by a crystal which forms one of a group of dull but well-formed scalenohedral crystals of Proustite from Marienberg, and is represented in fig. 28.

A specimen of Proustite from Himmelsfürst Mine, Freiberg, is also perhaps an example of the same law.

Though this law is given in all the text books as a mode of twinning common in Pyrargyrite, I have found no case of apparent twinning on the basal plane which does not, on careful examination, prove to be due to the third law.

It must be noted that without direct evidence of the hemimorphism of Proustite, it is impossible to say whether this law is to be described as twinning upon o $\{111\}$, or upon b $\{2\bar{1}\bar{1}\}$. See figs. 15, 16.

(5). Twin-plane $e = 110 = -\frac{1}{2}R$.

This law is exemplified by two specimens from Markirch in the Museum collection, which are prisms of Proustite having lamellæ parallel to the face e; also, perhaps, by a group of scalenohedral crystals of Proustite from Freiberg. A specimen of Pyrargyrite of scalenohedral habit from Freiberg in the Ludlam collection appears to be twinned according to this law, the two individuals being, as usual, on the same side of the twin-plane.

(6). Twin-plane $b = 2\bar{1}\bar{1} = \infty R$.

This law rests upon the authority of Haidinger (*Ed. J. Sc.* I. 1824, p. 326, figs. 14-17); it would require re-examination to determine whether the law is to be so expressed, or to be described as twinning about o with composition parallel to b.

§ 18.—Principal (Curved and Striated[1]) Zones.

The striated zones of any mineral deserve particular attention. If the reflections obtained on the goniometer are not carefully criticised and distinguished, there will be a tendency to accept as typical faces (from the mean of several images) precisely those forms which do not occur as such, but are replaced by vicinal faces; this is what was certainly done in many cases by the earlier observers; for example, the face $A = 15\ 3\ \bar{4}$, given by Sella, is almost invariably replaced by the faces $L = 19\ 4\ \bar{5}$ and $x' = 26\ 5\ \bar{7}$ in the group between VB, and is certainly not the typical face in this region of the crystal; on the other hand, if equal importance is attached to all the reflecting surfaces, the zone becomes filled with a continuous series of planes which are difficult of interpretation.

Several authors have insisted[2] that to ascertain the indices of vicinal faces, and faces in striated zones, it is not enough to take the mean of several measurements, but that these planes are to be regarded as local developments, and the individual measurements on each crystal must determine the faces present. On the other hand, a difference of a few minutes in the measurements introduces an enormous difference in the symbol of a face with high indices; now even the faces of the rhombohedra (100) and (110) have been shown above to be subject to local distortions from their true positions even when they are perfectly smooth and bright and not complicated by vicinal faces, so that definite symbols cannot be assigned to planes with very high indices until there is some proof that the measurements can be relied upon to three or four minutes.

In dealing with the striated zones of Pyrargyrite it has therefore seemed safer to ascertain which faces with simple symbols are not developed in

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[1] Zones rich in faces are striated when the faces tend to make re-entrant angles, curved when they form salient angles.

[2] Hintze, *Zeitsch. f. Kryst.* XI. p. 234.

these zones but are replaced by groups of neighbouring faces, and what are the symbols which the replacing planes tend to assume, and finally, to compare these with the typical forms by which the zone or a part of the zone is occasionally represented.

For this purpose the whole series of *definite* reflections obtained on the goniometer from a striated zone upon a number of crystals is reduced to angular distances from some one face in the zone;[1] these are all ranged in parallel columns so that the same values fall upon horizontal lines; it is then found that the readings fall into well-defined groups; the mean of each group is taken to form a new column which represents a first approximation to the faces of the zone (vicinal faces of the first order ?); the individual variations within each group (vicinal faces of the 2nd order ?) cannot safely be expressed in terms of indices, and must for the present be neglected.

A comparison of the angles so found with those of the typical faces which occur as bright planes unaccompanied by striated series, shows that the new column contains all the typical faces, and in addition others which, if they recur with regularity and vary within small limits, must be regarded as true faces of the zone, and which it may be hoped will throw some light upon the laws that govern the development of these complicated zones.

The richest zones in Pyrargyrite are :—

(1.) *era*, the parts between *er*, and between *ra*.

(2.) *brδ*, the parts between *bE*, and between *rμ*.

(3.) *bVe*, the part between *VB*.

(4.) *ee*, the part between *ee*.

Oscillatory combinations or striated faces have also been observed between *bX*, *ea*, *asa*, and in the neighbourhood of *Y* in the zone *rY*, in Pyrargyrite; between *es*, and on the prism edges, in Proustite. Sella,[2] in a paper which was evidently the outcome of his study of the Red Silvers, has laid it down as a law that when a zone is characterised by a series of striated faces, *i.e.* is an important zone upon the crystal, the conjugate face (that is, the face which has the same symbol as the zone) is distinguished by its perfection and brightness. This statement is not supported by a more complete study of the minerals, since the four faces corresponding to the first four zones mentioned above are :—

(1.) $r = 100$ which is bright and perfect.

(2.) $p = 210$ which is generally striated, sometimes bright.

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[1] Care is taken to repeat the measurements at various angles of incidence, so that the reflections which correspond to true planes can be selected.

[2] *Il Nuovo Cimento* IV. 1856, p. 103.

(3.) $31\bar{1}$ which does not exist.

(4.) $s = 11\bar{1}$ which is bright and perfect.

While striated zones corresponding to *e v t a*, the four most perfect faces on both minerals, are not to be found.

The following tables give in the first three columns the results obtained from measurement of the above-mentioned zones, where they are developed as striated series. The adjacent columns give the calculated angles for those faces which have been established by independent measurements upon definite faces.

A. Observations.

(1.) Zone *e r a*. Striated; *e r* sometimes curved.

e : *h k* 0.	Limits.	Number.	Known Forms.	*h k* 0.	Calculated.
4° 59′	....	1	Λ	540	4° 34′
7 17	....	1	*z*′	430	5 52
10 32		1	*v*	320	8 11
12 1	11° 54′—12° 7′	3	*ω*	530	10 11
12 54	12 42—13 2	9	Σ	13 7 0	12 10
13 25	13 11—13 44	24	*p*	2 1 0	13 28
13 43	13 34—13 47	7	..	..	..
14 11	14 1—14 17	3	..	..	..
14 33	14 30—14 37	3	..	..	..
14 50	14 37—14 59	6	Π′	13 6 0	14 50
15 16	15 12—15 20	2	..	..	..
15 51	15 44—15 57	3	Γ′	730	16 2
16 34	16 30—16 41	4	..	..	..
17 0	....	1	Υ	520	17 7
17 30	17 23—17 31	4	*r*′	830	18 5
18 21	18 0—18 51	7	λ	11 4 0	18 32
19 40	19 26—20 5	16	*t*	310	19 46
22 25	....	1	*e*′	10 3 0	21 9
22 40	....	1	*θ*′	720	21 46
23 10	....	2	*w*	410	23 19
23 36	....	1	..	..	..
24 19	....	1	..	..	..
25 24	25 9—25 32	5	*φ*	510	25 36
31 1	....	1	*ξ*	610	27 10

A. OBSERVATIONS.

(1.) Zone *e r a*. Striated; *e r* sometimes curved—*Continued.*

e : *h k* 0.	Limits.	Number.	Known Forms.	*h k* 0.	Calculated.
33° 30′	33° 19′—33° 48′	5	*G′*	810	29 12
34 20	34 12—34 27	2	..	..	..
35 38	35 27—35 41	14	*r*	100	35 41
36 4	36 0—36 8	2	*w′*	$50\bar{1}$	47 8
			n	$40\bar{1}$	50 8
43 26	....	1	*ψ*	$30\bar{1}$	55 10
61 7	....	1	*s′*	$70\bar{3}$	60 54
65 12	64 49—65 43	9	*v*	$20\bar{1}$	65 7
65 48	....	1	..	..	..
66 20	66 11—66 28	2	..	..	..
67 22	67 19—67 24	2	..	..	..
68 27	....	1	*ζ*	$90\bar{5}$	68 19
69 40	69 29—69 50	2	..	..	..
70 44	....	1	*γ*	$50\bar{3}$	70 49
71 12	71 11—71 14	3	..	..	..
72 37	72 30—72 44	2	..	..	..
73 35	73 34—73 36	2	*I′*	$17\ 0\ \overline{11}$	73° 24′
73 57	....	1	..	..	..
74 28	74 17—74 47	11	*y*	$30\bar{2}$	74 27
75 5	75 2—75 18	8	..	..	..
75 32	75 30—75 34	2	Δ	$19\ 0\ \overline{13}$	75 22
75 58	75 56—75 58	3	..	..	..
76 21	76 16—76 28	4	Ω	$10\ 0\ \bar{7}$	76 12
77 38	77 31—77 44	2	*κ*	$70\bar{5}$	76 56
78 18	78 4—78 31	7	..	..	..
78 49	78 45—78 57	4	*c*	$40\bar{3}$	78 45
79 19	79 11—79 37	4	Δ′	$17\ 0\ \overline{13}$	79 29
80 32	....	1	*π′*	$90\bar{7}$	80 8
81 11	....	1	*Z*	$50\bar{4}$	81 13
81 48	81 40—81 56	2	..	..	..
82 11	82 5—82 17	3	..	..	..
82 40	82 25—82 54	4	..	..	..
83 40	83 30—83 58	5	..	..	..
84 25	84 15—84 36	3	..	..	..
85 10	85 5—85 15	2	*N′*	$17\ 0\ \overline{15}$	85 2
85 43	....	1	..	..	..
86 5	86 3—86 7	2	..	..	..
86 58	....	1	..	..	..

(2.) Zone $b\,r\,\delta$. Generally curved.

(*a*.) Series *b* to *E*.

$b:\ h\,k\,l.$	Limits.	Number.		$h\,k\,l.$	Calculated.
6° 19′	6° 3′—6° 46′	3	*D*	$54\bar{8}$	6° 23′
7 30	....	1	..	..	..
7 43	....	1	*G*	$43\bar{6}$	8 22
10 37	10 13—10 46	3	..	..	..
11 45	11 22—11 58	3	..	.	..
12 17	12 3—12 26	5	*q*	$32\bar{4}$	12 8
12 41	....	1	..	..	..
13 18	....	1	..	..	..
14 38	14 28—14 45	4	*H*	$8\,5\,\overline{10}$	14 16
15 2	....	2	..	..	..
15 12	15 11—15 13	2	..	..	..
15 24	15 22—15 25	2	*N*	$53\bar{6}$	15 37
15 50	15 39—16 2	3	..	..	..
16 40	....	2	..	..	..
16 53	....	1	..	..	..
17 20	17 19—17 21	2	Ω′	$74\bar{8}$	17 15
17 31	17 28—17 33	3	..	..	..
17 47	17 43—17 55	7	..	..	..
18 9	18 3—18 13	6	*F*	$9\,5\,\overline{10}$	18 12
18 23	18 21—18 26	3	*K*′	$13\,7\,\overline{14}$	19 16
18 43	18 36—18 53	4	*E*	$21\bar{2}$	21 46

(*b*.) Series between $r\,\mu$.

$r:\ h\,k\,l.$	Limits.	Number.	$h\,k\,l.$	Calculated.
4° 41′	4° 24′—4° 50′	3	$23\,2\,\bar{1}$	4° 40′
5 26	5 21—5 31	2	$20\,2\,\bar{1}$	5 21
6 22	6 10—6 37	3	$17\,2\,\bar{1}$	6 16
8 11	7 43—8 19	3	$13\,2\,\bar{1}$	8 8

This group occurs as striated faces on the corner of the rhombohedron *r* (100) upon a specimen of Pyrargyrite from Freiberg, which is a combination ot the prism *a* with *q* and *b*, terminated by *r t*.

(3.) Zone *b V e*. Generally curved.

b : *h k l*.	Limits.	Number.		*h k l*.	Calculated.
39° 14′	39° 2′—39° 27′	9	*V*	13 1 $\bar{4}$	39° 8′
39 41	....	1	..	..	..
40 34	....	1	..	..	..
41 13	....	1	..	..	..
43 26	43 23—43 32	3	*g*	71$\bar{2}$	43 20
44 28	44 14—44 42	2	..	..	..
45 22	45 13—45 36	5	*F′*	40 7 $\overline{11}$	45 19
45 42	45 30—45 54	2	..	..	..
46 23	46 2—46 47	12	*x′*	26 5 $\bar{7}$	46 21
46 54	....	1	*A*	15 3 $\bar{4}$	46 49
47 28	47 7—47 46	11	*L*	19 4 $\bar{5}$	47 26
48 10	48 0—48 16	5	Ξ	27 6 $\bar{7}$	48 7
48 48	....	1	..	..	..
49 37	49 24—49 54	5	*σ*	41$\bar{1}$	49 42
50 24	50 1—50 43	4	..	..	..
50 58	50 54—51 37	3	..	..	..
52 5	51 51—52 25	11	*B*	17 5 $\bar{4}$	52 9
53 2	....	1	*K*	21 6 $\bar{5}$	53 5

(4.) Zone *ee*. No definite measurements could be obtained in this zone.

B. Indices of Faces in Striated Zones.

The above Tables represent a series of carefully selected measurements, and may be useful as data to be employed at some future time in the general discussion of striated zones.

Max Schuster, in his laborious memoir on the vicinal faces of danburite, has endeavoured to show how their regularity may be expressed in terms of the indices; Professor Hintze, on the other hand, suggests that the vicinal faces indicate local variations which may with equal propriety be expressed in terms of their direct angular relations, a succession of vicinal faces in celestine being, for example, inclined to one another at equal angles. It will be enough in the present instance to point out certain features of regularity which characterise some parts of the crowded zones in Pyrargyrite.

This regularity may be expressed either in terms of the indices or of the angles; but not in a series of direct angular differences, as was the case with celestine; and therefore denotes some law of progression resulting from the internal structure of the crystal, and not merely a superficial and local phenomenon. The functions chosen below to indicate the regularity are used because convenient for calculation, but they may easily be translated into the nomenclature of Schuster or Websky.

(1). Zone *era*. Here the function $\frac{h+k}{h-k} = \frac{\tan\theta}{\tan er}$ (or the anharmonic ratio of the four faces e, r, $(hk0)$, a), where θ is the angle $e:(hk0)$, proceeds by a series of fractions in which different numbers play an important part in different portions of the zone. For the crowded region between *pt* the value of $h-k$ is 7 or a multiple of 7, between *yc* it is 5 or a multiple of 5. This will be clear from the following tables:—

$e:(h\,k\,0)$.	$(h\,k\,0)$.	$\frac{\tan\theta}{\tan er}$
12° 53′	29 15 0	$\frac{7}{22}$
13 28	210	$\frac{7}{21} = \frac{1}{3}$
13 47	55 27 0	$\frac{14}{41}$
14 7	27 13 0	$\frac{7}{20}$
14 28	53 25 0	$\frac{14}{39}$
14 50	13 6 0	$\frac{7}{19}$
15 13	51 23 0	$\frac{14}{37}$
16 2	730	$\frac{14}{35} = \frac{2}{5}$
16 29	12 5 0	$\frac{7}{17}$
16 57	47 19 0	$\frac{14}{33}$
17 27	23 9 0	$\frac{7}{16}$
18 32	11 4 0	$\frac{7}{15}$
19 46	310	$\frac{7}{14} = \frac{1}{2}$

The above series may be tested by the following very good measurements, derived from two exceptionally perfect Andreasberg crystals taken from two specimens:—

$e:(h\,k\,0)$.	Limits.	Number.
12° 57′	12° 53′—12° 58′	4
13 27	13 21—13 32	5
13 45	13 41—13 49	3
14 49	... ...	1
16 33	... ...	1
19 41	19 39—19 43	6

The crowded portion of the zone between yc may be compared with the following calculated values :—

$e:(h\,0\,k)$.	$(h\,0\,k)$.	$\dfrac{\tan\theta}{\tan er}$
74° 27′	$30\bar{2}$	$\frac{25}{5}=5$
75 1	$31\ 0\ \overline{21}$	$\frac{26}{5}$
75 33	$16\ 0\ \overline{11}$	$\frac{27}{5}$
76 3	$33\ 0\ \overline{23}$	$\frac{28}{5}$
76 30	$17\ 0\ \overline{12}$	$\frac{29}{5}$
77 44	$37\ 0\ \overline{27}$	$\frac{32}{5}$
78 26	$39\ 0\ \overline{29}$	$\frac{34}{5}$
78 45	$40\bar{3}$	$\frac{35}{5}=7$
79 21	$21\ 0\ \overline{16}$	$\frac{37}{5}$

(2). Zone bE. Here we may take the function $\dfrac{h+5k}{h-k}$ which is equal to the ratio $\dfrac{\tan br}{\tan\theta}$ [or the anharmonic ratio of the four faces b, (hkl), r, $(5\bar{1}2)$] where $\theta = b:(hkl)$ and the following angles calculated from a series proceeding by differences of sevenths agree very closely with the measured angles. (See Table on page 90.)

Here then, between the positions of $(18\ 11\ \overline{22})$ and $(31\ 17\ \overline{34})$ at least, the value of $h-k$ is a multiple of 7, and the function $\dfrac{h+5k}{h-k}$ proceeds by equal increments.

(3.) Zone bVe. The group of faces between VB is found on certain specimens from Andreasberg, probably from the Morgenrothe mine, which have the habit of the crystal figured by Phillips.

This is the most perplexing zone on the mineral, there cannot be the least doubt that

$$V = 13\ 1\ \bar{4},\quad x' = 26\ 5\ \bar{7},\quad L = 19\ 4\ \bar{5},\quad B = 17\ 5\ \bar{4}$$

are well-defined typical faces in the zone ; the remainder are perhaps induced by these.

The group scarcely ever extends beyond B on the one side and V on the other (the doubtful face given above as $21\ 6\ \bar{5}$ was only observed once).

It is possible that the zones connecting this set of faces with the face v $(20\bar{1})$ may contain the group of faces between ϕ (510) and ω (530) ; if

$b : h k l.$	$h k l.$	$\frac{\tan br}{\tan \theta} = \frac{h+5k}{h-k}$
6° 23′	5 4 $\bar{8}$	$\frac{175}{7} = 25$
7 35	13 10 $\overline{20}$	$\frac{147}{7} = 21$
7 41	30 23 $\overline{46}$	$\frac{145}{7}$
10 34	10 7 $\overline{14}$	$\frac{105}{7} = 15$
11 46	43 29 $\overline{58}$	$\frac{94}{7}$
12 8	324	$\frac{91}{7} = 13$
12 41	61 40 $\overline{80}$	$\frac{87}{7}$
13 7	17 11 $\overline{22}$	$\frac{84}{7} = 12$
14 38	55 34 $\overline{68}$	$\frac{75}{7}$
15 0	18 11 $\overline{22}$	$\frac{73}{7}$
15 12	107 65 $\overline{130}$	$\frac{72}{7}$
15 25	53 32 $\overline{64}$	$\frac{71}{7}$
15 50	52 31 $\overline{62}$	$\frac{69}{7}$
16 45	50 29 $\overline{58}$	$\frac{65}{7}$
17 0	33 19 $\overline{38}$	$\frac{64}{7}$
17 15	74$\bar{8}$	$\frac{63}{7} = 9$
17 31	97 55 $\overline{110}$	$\frac{62}{7}$
17 47	48 27 $\overline{54}$	$\frac{61}{7}$
18 4	95 53 $\overline{106}$	$\frac{60}{7}$
18 21	47 26 $\overline{52}$	$\frac{59}{7}$
18 39	31 17 $\overline{34}$	$\frac{58}{7}$

this is so the zone VB may be described as the projection of the zone re from the face v.

This is indicated by the following table, in which the first column gives the symbols of faces between re, the second column gives their projections from v upon the zone be, and the second and third columns the corresponding symbols and angles in the zone be.

Here, although the important faces LB have not their representatives in the zone er, it appears possible that the general law of progression in the series may be derived from that of the zone er. In this case, since the projection of a face $(hk0)$ will have the symbol $(3h-2k,\ k,\ k-h)$, the vicinal faces in the zone VB will have their last index a multiple of 7.

Zone *r e*. Symbol.	Zone *b e*. Symbol.	Angle.	
510	$13\ 1\ \bar{4}$	39° 8′	*V*
(920)	$23\ 2\ \bar{7}$	39 47	
410	$10\ 1\ \bar{3}$	40 37	
(19 5 0)	$47\ 5\ \overline{14}$	41 2	
310	$71\bar{2}$	43 20	*g*
11 4 0	$25\ 4\ \bar{7}$	44 24	
23 9 0	$51\ 9\ \overline{14}$	45 24	
47 19 0	$103\ 19\ \overline{28}$	45 53	
12 5 0	$26\ 5\ \bar{7}$	46 21	*x′*
730	$15\ 3\ \bar{4}$	46 49	*A*
(940)	$19\ 4\ \bar{5}$	47 26	*L*
13 6 0	$27\ 6\ \bar{7}$	48 7	*Ξ*
27 13 0	$55\ 13\ \overline{14}$	48 56	
210	$41\bar{1}$	49 42	*σ*
29 15 0	$47\ 15\ \overline{14}$	50 27	
(15 8 0)	$29\ 8\ \bar{7}$	51 9	
(950)	$17\ 5\ \bar{4}$	52 9	*B*

C. Position of Striated and Curved Groups.

(1). The position of the group $V - B$ is marked by a curious feature. If ∇ is the point at which the zone bVe approaches most nearly to the plane r, so that $b\nabla$ is at right angles to VB, then $b\nabla = 45°35'$; now this is exactly the centre of the group $V - B$, the inclinations being $V\nabla = 6°38'$, $B\nabla = 6°31'$. Hence the crowded part of the zone *be* is precisely the region where it approaches most closely to the rhombohedron *r*, and it extends to an equal distance on both sides of the nearest point; the group terminates abruptly at the planes *V* and *B*, which are distant from *b* by $\frac{1}{2}$ and $\frac{4}{5}$ respectively of the total angular distance *be*.

(2). The point where the zone *av* $(10\bar{1} : 20\bar{1})$ approaches most nearly to *b* $(2\bar{1}\bar{1})$ is a plane inclined at 78°17′ to *e* (101), and this is exactly the point where the striated faces are most thickly developed.

(3). The point at which the zone *bqr* approaches most nearly to the plane *a* is distant $12°45\frac{1}{2}'$ from *b*, and this is a plane nearly coinciding in position with the face *q*.

In some instances, therefore, at the point where a principal zone of a Pyrargyrite crystal approaches most nearly to one of the principal faces lying outside the zone, the zone is, as it were, unstable, and liable to develope vicinal faces belonging to the same zone.

§ 19.—Isolated Groups of Vicinal Faces.

We here consider groups of planes with high indices which replace or accompany typical faces.

The faces between $(23\ 2\ \bar{1})$ and $(13\ 2\ \bar{1})$ given above form one such group. Another is the series of four faces in the zone $r\tau$ $[100 : 21\bar{3}]$ which replace the face i_3 of the crystal described by Phillips, and which extend from $Y = 81\bar{3}$ to $61\bar{3}$, as follows :—

$r : (h\ k\ l)$.	Limits.	Number.	Symbol.	Calculated.
20° 44′	20° 41′—20° 49′	2	$81\bar{3}$	20° 37′
24 28	24 12—24 40	2	$20\ 8\ \bar{9}$	24 41
26 11	... ...	1	$25\ 4\ \overline{12}$	26 16
27 29	27 22—27 34	2	$61\bar{3}$	27 19

The face r (100) is accompanied on a crystal of Pyrargyrite from Freiberg by a pair of planes replacing the edges which it makes with two faces of the form e (110), which are inclined to r at the angles 1°53′ and 2°1½′ respectively. Both these angles are capable of accurate measurement.

A crystal of Pyrargyrite from Andreasberg, which is terminated by *epr*, has four faces replacing the edges *ep*, and having the following inclinations to e :—

$e : (h\ k\ 0)$.	Limits.	Number.	Symbol.	Calculated.
2° 27′	2° 24′—2° 30′	2	71 63 0	2° 27′
2 54	2 53—2 54	2	61 53 0	2 53
3 30	3 26—3 35	2	51 43 0	3 30
4 16	4 11—4 19	2	41 33 0	4 26

This series seems without doubt to proceed by equal increments, not of angle but of indices. The scalenohedron v $(20\bar{1})$, on a crystal of Proustite from Chañarcillo, is accompanied by minute facets in the zone *av* [$10\bar{1} : 20\bar{1}$], three above *v* towards *r*, and three below *v* towards *a*.

Those above *v* are inclined to *v* at the angles 2°53′; 3°18′; 3°36′: those below at the angles 1°39′; 1°54′; 2°50′.

On a crystal of Pyrargyrite from Andreasberg the face *n* ($40\bar{1}$) at the attached end of the crystal which is inclined to the prism *a* ($10\bar{1}$) at 50°8′ is accompanied by four faces in the zone *na* which are inclined to *a* at the angles

48°44′; 48°55′; 47°48′; 43°19′.

On a crystal of Pyrargyrite from Andreasberg the face *r* (100) at the attached end is accompanied by two rhombohedral planes belonging to the same vertical series and inclined to *r* at the angles

6°23′	$r : 14\ \bar{1}\ \bar{1} = 6°23\frac{1}{2}'$
7°15′ – 7°46′	$r : 12\ \bar{1}\ \bar{1} = 7°29\frac{1}{2}'$

§ 20.—Disposition of the Faces.

The principal zones characteristic of the upper and lower ends of a Pyrargyrite crystal will be found in the edges of a combination of the prism *a* and trigonal prism *b* with the faces *r e v* at the upper end and terminated by *r e n* at the lower extremity, as is shown in fig. 2.

The characteristic zones of the upper end are then—

[*a v r e*] typical faces $N'\ y\ \gamma\ v\ \phi\ w\ t\ \lambda\ p$.

[*b e*] typical faces $V\ x'\ L\ B$, with $g\ F'\ A\ \Xi\ \sigma$.

[*v v*] typical faces $q\ f\ E\ T$.

[*v v*] typical faces $\alpha\ s$.

[*b r*] typical faces $T\ R\ u\ s\ \Gamma$, with I.

[*b v*] typical faces $X\ l\ d$, with $p'\ \rho$.

The characteristic zones of the lower end are—

[*b r*] typical faces $D\ q\ F\ E$, with $G\ H\ N$, &c.

[*a n r e*] typical faces $v\ n\ t\ p$, with $s'\ \psi\ w'$.

[*n n*] typical faces $\alpha\ Y\ \Pi$.

[*b e*] typical faces $f\ u$.

It will be seen from the projections that the poles mostly lie upon zones having simple symbols which radiate from the poles of *r* and *e* respectively. The notations G_1 and G_2 of Goldschmidt may be regarded as representing faces belonging to sets of zones which radiate from a pair of faces of the prisms *a* and *b* respectively. The symbols *p q* of the notation G_1, for instance (which are given above), are derived from the Millerian symbol $(h\,k\,l)$ as $p = \frac{h-k}{h+k+l}, q = \frac{k-l}{h+k+l}$

We might use a similar notation to express the faces as the intersections of zones radiating from r and e. Thus, taking the symbol $p\,q$ where $p = \frac{k}{-l}, q = \frac{h-k+l}{-l}$, it will be found that almost all the certain forms are denoted by very simple ratios, more simple than those of G_1 or G_2.

§ 21.—Chemical Composition.

The 15 analyses given below were made by Mr. G. T. Prior upon specimens in the Museum collection; they represent our endeavours to determine the composition and crystalline form of pure Pyrargyrite, pure Proustite, and varieties containing both antimony and arsenic; the manner in which the specimens were selected has been mentioned in § 5.

The analyses were conducted by methods which have been indicated in Vol. VII. p. 197. In all cases the mineral was decomposed in a current of chlorine.

In the case of Pyrargyrite (with the exception of No. 10) the separation, where necessary, of the small percentage of arsenic from the much larger percentage of antimony was effected by Fischer's method as modified by Hufschmidt and Classen; while in the case of Proustite the separation of the small percentage of antimony from the much larger percentage of arsenic was effected by means of magnesia mixture. In most of the analyses the sulphur was determined in a separate portion of the material.

When slowly and carefully conducted, the decomposition of the mineral in a current of chlorine determines the percentage of silver with great accuracy, so that this determination may be regarded as a guide to the composition of any specimen, for the analyses show that all the specimens examined (with the exception of No. 5) consist of mixtures of Pyrargyrite and Proustite. For this reason, coupled with the fact that no arsenic was detected in the specimen by the Fresenius and Babo method, we have given the silver determination alone of No. 2.

Fischer's method of separation of arsenic and antimony appears to be an excellent one when the proportion of arsenic is considerably less than that of the antimony; but in the reverse case a second distillation was generally required to effect the absolute separation. For this reason in the case of the Proustites the separation by means of magnesia mixture was used. By this method, however, it did not appear always possible to effect a perfectly absolute separation, for traces of arsenic passed through in the washings, so that the percentage of antimony in the Proustite specimens is doubtless a little too high, but not by more than 0·1 per cent.

Of the two rhombohedron angles given, the first is always that which was measured, and the second is calculated from it.

Pyrargyrite.

(1.) Catalogue number 29709.

Ag	... ...	59·75	Specific gravity = 5·82
S	... ...	17·81	
Sb	... ...	22·45	
		100·01	

Rhombohedron angle $ee = 42°5'$ $(42°4'37''—42°5'35'')$.

$\therefore rr = 71°22'$

Andreasberg. Typical specimen; lateral habit, prolate; termination, pyramidal; combination of $t\ v\ e\ a\ b\ p\ v\ \lambda\ \omega$, &c.; p a smooth bright face. A group of bright crystals on calcite; twinned on u.

(2.) Catalogue number 48555.

Ag ... 59·74 Specific gravity = 5·85 Contains no arsenic.

Rhombohedron angle $ee = 42°4\frac{1}{2}'$

$\therefore rr = 71°22'$

Santa Lucia mine, Guanaxuato, Mexico. Typical specimen; lateral habit, prismatic; termination flat (see § 4); combination of $a\ b\ e\ q\ u$, u forming a drusy basal plane. A group of bright prisms; twinned on a.

(3.) Catalogue number 37042.

Ag	... ...	59·91
S	... ...	17·79
Sb	... ...	22·09
As	... ...	0·12
		99·91

Rhombohedron angle $rr = 71°22'$

$\therefore ee = 42°5'$

Andreasberg (Abendrothe mine?). Lateral habit, scalenohedral; termination rhombohedral; combination of $a\ y\ V\ L\ e\ X\ b\ m'\ \omega\ p\ t\ w\ \phi\ \Delta\ B\ \Upsilon$ (without e and v). Bright crystals dispersed on calcite.

(4.) Catalogue number $A.\ G.$ 20.

Ag	... ...	60·04	Specific gravity = 5·83
S	... ...	17·74	
Sb	... ...	22·39	
As	... ...	0·27	
		100·44	

Galega mine, Zacatecas, Mexico. Habit prismatic; combination of *a b u* with *q r n* at the attached end. A group of large dull uneven crystals; twinned on *a*.

(5.) Catalogue number 37042 (3).

Ag	57·46
S	18·62
Sb	23·73
As	0·30
	100·11

Rhombohedron angle $rr = 71°22'$

$\therefore\ ee = 42°5'$

Andreasberg. Lateral habit, lanceolate; termination, rhombohedral; combination of $\Gamma\, q\, F\, a\, X\, r\, V\, L$, &c. A fine mass of crystals grouped on calcite, with galena and miargyrite; the lateral faces are coated with crystals of hypargyrite which partly penetrate them.

The analysis has evidently been vitiated by the presence of the hypargyrite, which was even visible in the crushed material. A mixture of 10 per cent. of miargyrite with 90 per cent. of Pyrargyrite would have the composition

Ag	57·55
S	18·46
Sb	23·99

(6.) Catalogue number 57648.

Ag	60·24	Specific gravity = 5·86
S	17·74	
Sb	21·69	
As	0·44	
	100·11	

Rhombohedron angle $rr = 71°10'$

$\therefore\ ee = 41·55\frac{1}{2}'$

Andreasberg. Lateral habit, lanceolate; termination, rhombohedral passing into pyramidal; combination of $a F y b q X V L r t e \phi x' B p \gamma Q p'$, with $r n \Pi s'$ at the attached end. Represented in fig. 8. The habit is similar to that of (3) (5), and of Phillips' crystal.

Bright drusy crystals on calcite with galena.

(7.) Catalogue number 29714.

Ag	60·17	Specific gravity = 5·78
S	17·65	
Sb	21·64	
As	0·52	
	99·98	

Rhombohedron angle $ee = 42°8'$
$\therefore rr = 71°25\frac{1}{2}'$

Freiberg. Lateral habit, prismatic; termination, rhombohedral. A large hollow crystal, a combination of *ab* with rough terminal planes, having a little Proustite (?) on its surface. The angle was taken from a small crystal (combination *e v Y*) from the inside of the specimen.

(8.) Catalogue number 34756.

Ag	...	...	60·07	Specific gravity = 5·77
S	...	...	17·89	
Sb	...	...	21·20	
As	...	...	0·79	
			99·95	

Chañarcillo. Lateral habit, prismatic; termination, rhombohedral; combination of *a e q r*, &c. Groups of bright crystals on calcite; twinned on *u*, *a*, and *r*.

(9.) Catalogue number *Cr. v. v.* 4.

Ag	...	...	60·21	Specific gravity = 5·81
S	...	...	17·78	
Sb	...	...	20·69	
As	...	...	1·02	
			99·70	

Harz. Lateral habit, prismatic; termination, pyramidal; combination of *a t* with *arnvqu* at the other end; represented in fig. 3; twinned on *a*; large uneven doubly terminated crystals with calcite, galena, mispickel (?), and a little tetrahedrite; the crystals are too drusy for accurate measurement;[1] they are somewhat light coloured (this may perhaps be due to their drusy character).

(10.) Catalogue number 34435.

Ag	...	...	60·85	Specific gravity = 5·805
S	...	...	17·99	
Sb	...	...	18·36	
As	...	...	2·60	
			99·80	

Rhombohedron angle $rr = 71°30'$
$\therefore ee = 42°11\frac{1}{2}'$

Andreasberg. A small mass of bright light-coloured crystals of the habit and combination shown in fig. 4. The prism faces are smooth, but

[1] Two edges yielded accurate measurements $vv = 35°13'$ and $nn = 17°37'$. The first leads to $ee = 42°15'$, the second to $41°19'$.

the e-faces are uneven and concave; these crystals form a crust overlying a compact drusy mass, from which it is partly separated by drusy cavities; this mass consists of very minute crystals bearing the faces *a e s v y t*, and the rhombohedron angle is deduced from the measurements $vv = 74°27'$, $av = 24°51'$ made upon these; the rhombohedron was not capable of direct measurement, consequently much reliance cannot be placed upon the measurements. The analysis was made upon material consisting of both the crystalline crust and drusy mass; it was impossible to obtain enough of either singly without destroying the specimen, since the whole group did not weigh 7 grams. The streak on paper is that of Pyrargyrite, the colour of the powder in a tube is somewhat lighter than that of pure Pyrargyrite.

Proustite.

(1.) Catalogue number 26751.

Ag	65·39	Specific gravity = 5·57
S	19·52	
As	14·98	
	99·89	

Rhombohedron angle $ee = 42°46'$

$\therefore rr = 72°12'$ (observed $72°6'$)

Mexico. Massive and in bright crystals, on calcite; combination of *a v r e w* Ψ *M d s*; represented in fig. 7; twinned on *r*.

(2.) Catalogue number 39862.

Ag	65·37	Specific gravity = 5·59
S	19·24	
As	14·81	
Sb	0·59	
	100·01	

The antimony here is undoubtedly too high.

Rhombohedron angle $ee = 42°46'$

$\therefore rr = 72°12'$

Chañarcillo. Bright detached scalenohedral fragments; combination of *a v e s M w* Ψ.

(3.) Catalogue number 35832.

Ag	65·38	Specific gravity = 5·58
S	19·31	
As	14·89	
Sb	0·26	
	99·84	

Rhombohedron angle $ee = 42°45\frac{1}{2}'$
$rr = 72°12'$

Chañarcillo. Bright detached scalenohedral crystals; combination of *a v e*, &c.; twinned on *u* and *r*.

(4.) Catalogue number 62322.

Ag	... ...	65·06	Specific gravity = 5·64
S	... ...	19·64	
As	... ...	13·85	
Sb	... ...	1·41	
		99·96	

Rhombohedral angle $ee = 42°46'$
$\therefore rr = 72°12'$

Chañarcillo. Bright crystals on calcite; combination of *e v s P*; parts of this specimen contain 3·53 per cent. of antimony; it has been fully described in *Min. Mag.* VII. p. 197.

(5.) Catalogue number 34423.

Ag	... ...	64·43
S	... ...	19·54
Sb	... ...	3·74
As	... ...	12·28 (by difference)

Saxony? Large uneven prismatic crystals consisting of Proustite, surrounded with a shell of Pyrargyrite; combination of *a e q*, with smaltite, calcite, pyrrhotite and fluor. The analysis was made upon the interior of the specimen. A minute crystal protruding from the surface yielded an approximate measurement $ee = 41°24'$.

§ 22.—Connection between Composition, Form, Mode of Occurrence, &c.

The variations in the rhombohedron angle among the whole series of Pyrargyrites analysed fall within the irregular variations on individual specimens, and cannot be attributed to the presence of varying quantities of arsenic; the same is true of Proustite containing antimony.

The rhombohedron angle of Pyrargyrite free from arsenic is (as was shown in § 7) 71°22′ to a very close degree of approximation; that of Pyrargyrite containing arsenic in varying quantities (from a trace to 2·6 per cent.) determined in the same way is $71°22\frac{1}{2}'$, the limits being 71°10′ to 71°26′. This is the result of direct measurement of the rhombohedron faces, from 36 crystals belonging to 18 specimens from Andreasberg, Laasphe, Freiberg, Schneeberg, Bräunsdorf, Hiendelaençina, Guanaxuato, Zacatecas, and from unknown localities.

The presence of arsenic in all these has been proved by the Fresenius-Babo method.

No certain connection can be traced between the presence of arsenic in Pyrargyrite and the habit or appearance of the crystals; specimens of identical appearance sometimes contain a small percentage of arsenic and are sometimes free from it; and some Pyrargyrite of rather light colour is found to contain no arsenic.

The 22 specimens of pure Pyrargyrite examined include crystals of the four lateral habits mentioned in § 6, and of pyramidal and rhombohedral terminations; they are from the following localities:—Andreasberg, Gonderbach, Freiberg, Hiendelaençina, Guanaxuato, Zacatecas, and Peru; the associated minerals are calcite, galena, stephanite, quartz, stibnite, copper pyrites, chalybite, barytes, blende; and, in two instances from the Harz, arsenic.

The forms found upon these specimens are—

$$e\, v\, a\, t\, b\, p\, v\, \lambda\, \omega\, y \quad U\, r\, f\, P\, s\, u\, q\, w\, \theta\, a.$$

The Pyrargyrite from Hiendelaençina, and most of that from Laasphe, is remarkably free from arsenic.

§ 23.—Specific Gravity.

The following determinations were made; most of these have been already given with the analyses in § 21.

Pyrargyrite.

	Sp. Gr.	Weight.	Method.	Arsenic.	Angle *ee*.
(1)	5·86	5·0 grams	Pyknometer	0	42° 4½′
	5·85	2·2 ,,	Hydrostatic	....	..
(2)	5·85	4·0 ,,	Pyknometer	0	42 4½
(3)	5·85	22·2 ,,	Hydrostatic	Trace	42 6
(4)	5·84	24·0 ,,	,,	Trace	..
(5)	5·84	6·0 ,,	,,	Small percentage	..
(6)	5·84	44·8 ,,	,,	0	..
(7)	5·82	4·0 ,,	Pyknometer	0	42 5
	5·82	8·8 ,,	Hydrostatic	....	..
(8)	5·83	2·5 ,,	Pyknometer	0·27 per cent.	..
(9)	5·86	0·8 ,,	,,	0·44 ,,	41 56
(10)	5·80	1·9 ,,	,,	2·60 ,,	..
(11)	5·81	5·0 ,,	,,	1·02 ,,	..
(12)	5·78	10·4 ,,	Hydrostatic	0·52 ,,	42 8
(13)	5·77	2·5 ,,	Pyknometer	0·79 ,,	..

Proustite.

	Sp. Gr.	Weight.	Method.	Antimony.	Angle *ee*.
					° ′
(1)	5·55	7·7 grams	Hydrostatic	....	..
(2)	5·57	0·9 ,,	Pyknometer	0	42 46
(3)	5·58	2·7 ,,	,,	0·26	42 45½
(4)	5·59	2·3 ,,	,,	0·59	42 46
(5)	5·59	4·5 ,,	,,	....	..
(6)	5·60	15·3 ,,	Hydrostatic	....	..
(7)	5·62	50·5 ,,	,,	....	..
(8)	5·64	2·4 ,,	Pyknometer	1·41	42 46

Specimens referred to in the above Table.

Pyrargyrite.

(1.) Samson Mine, Andreasberg; very fine crystals, *a t e v y s P u q*.
(2.) Analysis 2.
(3.) Samson Mine, Andreasberg; fine crystals, *p a r e y h s Z P q*.
(4.) Andreasberg; fine crystals, *t v e y a b e q n G*.
(5.) Freiberg; large hollow scalenohedral crystal; habit of Proustite.
(6.) Harz; light coloured mass of crystals, *a v t*.
(7.) Analysis 1.
(8.) Analysis 4.
(9.) Analysis 6.
(10.) Analysis 10.
(11.) Analysis 9.
(12.) Analysis 7.
(13.) Analysis 8.

Proustite.

(1.) Chañarcillo; fine group; shown in fig. 27.
(2.) Analysis 1.
(3.) Analysis 3.
(4.) Analysis 2.
(5.) Chili; clear fragments.
(6.) Chañarcillo; fine group, *c s e u*.
(7.) Andreasberg; large mass of crystals, *t a e*.
(8.) Analysis 4.

EXPLANATION OF FIGURES.

PLATES IV.-V.

Fig.
1. Ideal combination of a doubly-terminated Pyrargyrite crystal.
2. The same, showing the typical zones.
3. Pyrargyrite from Andreasberg; hemimorphic.
4. Ditto, hemimorphic.
5. Ditto, showing the striations on the prism faces, hemimorphic.
6. Ditto, hemimorphic.
7. Proustite from Mexico.
8. Pyrargyrite from Andreasberg.
9. Ditto.
10. Typical Pyrargyrite crystal.
11. Typical Proustite crystal.
12. Proustite from Chañarcillo.
13. Pyrargyrite from Mexico showing twin-lamina.
14. Hemimorphic prism of Pyrargyrite.
15. Fig. 14 after hemitropy about the vertical axis.
16. Fig. 14 after hemitropy about normal to b $(2\bar{1}\bar{1})$.
17. Fig. 14 after hemitropy about normal to a $(10\bar{1})$.
18. Composition of 14 and 17 with q-ends outwards.
19. Composition of 14 and 17 with q-ends inwards.
20. Fig. 14 after hemitropy about the edge qr.
21. Fig. 14 after hemitropy about axis perpendicular to qr (u-twin).
22. Composition of 14 and 20.
23. Composition of 14 and 21.
24. Twin on u (211) developed on one side of the twin-plane.
25. Twin on u (211) developed on both sides of twin-plane.
26. Interpenetrating a-twin of Pyrargyrite.
27. Compound crystal of Proustite twinned on u and r.
28. Proustite twinned on o (111).

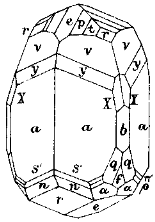
PLATE VI.

Gnomonic projection of all the certain forms.

PLATE VII.

Stereographic projection of the typical forms.

The *letters* in the right-hand sextant represent those of Pyrargyrite, and in the left-hand sextant those of Proustite.



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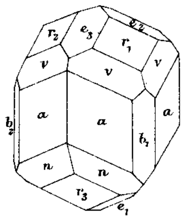

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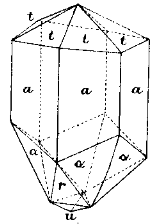

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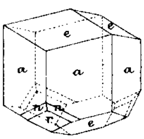

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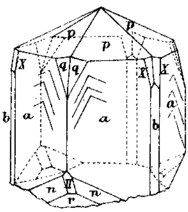

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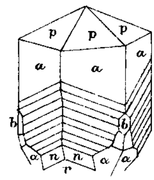

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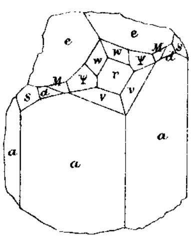

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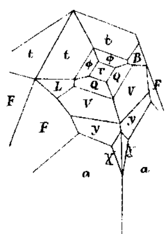

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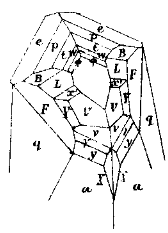

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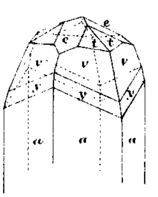

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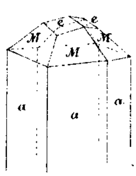

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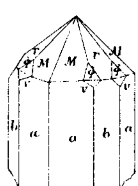

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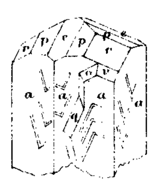

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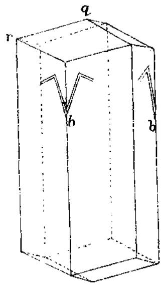
Mintern Bros. lith.



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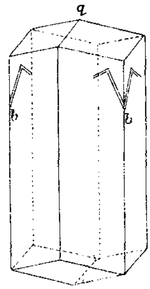

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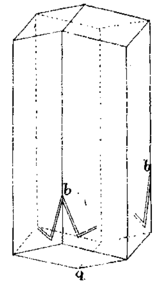

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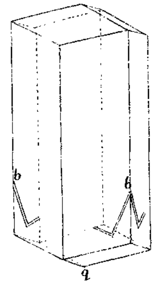

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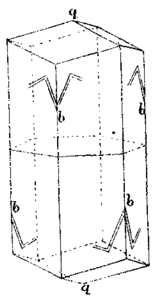

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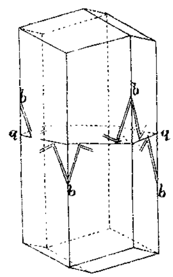

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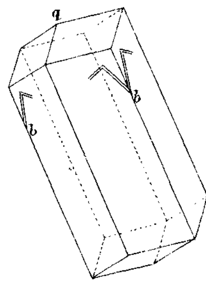

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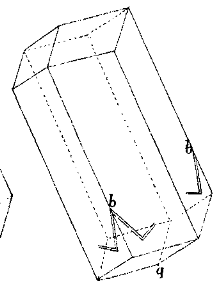

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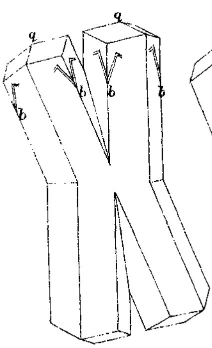

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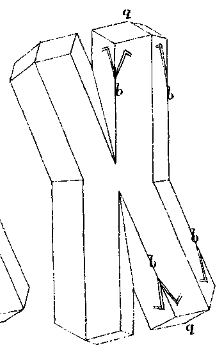

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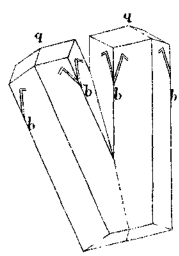

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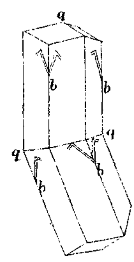

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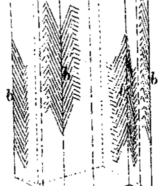

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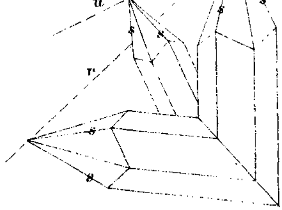

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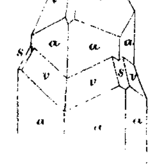

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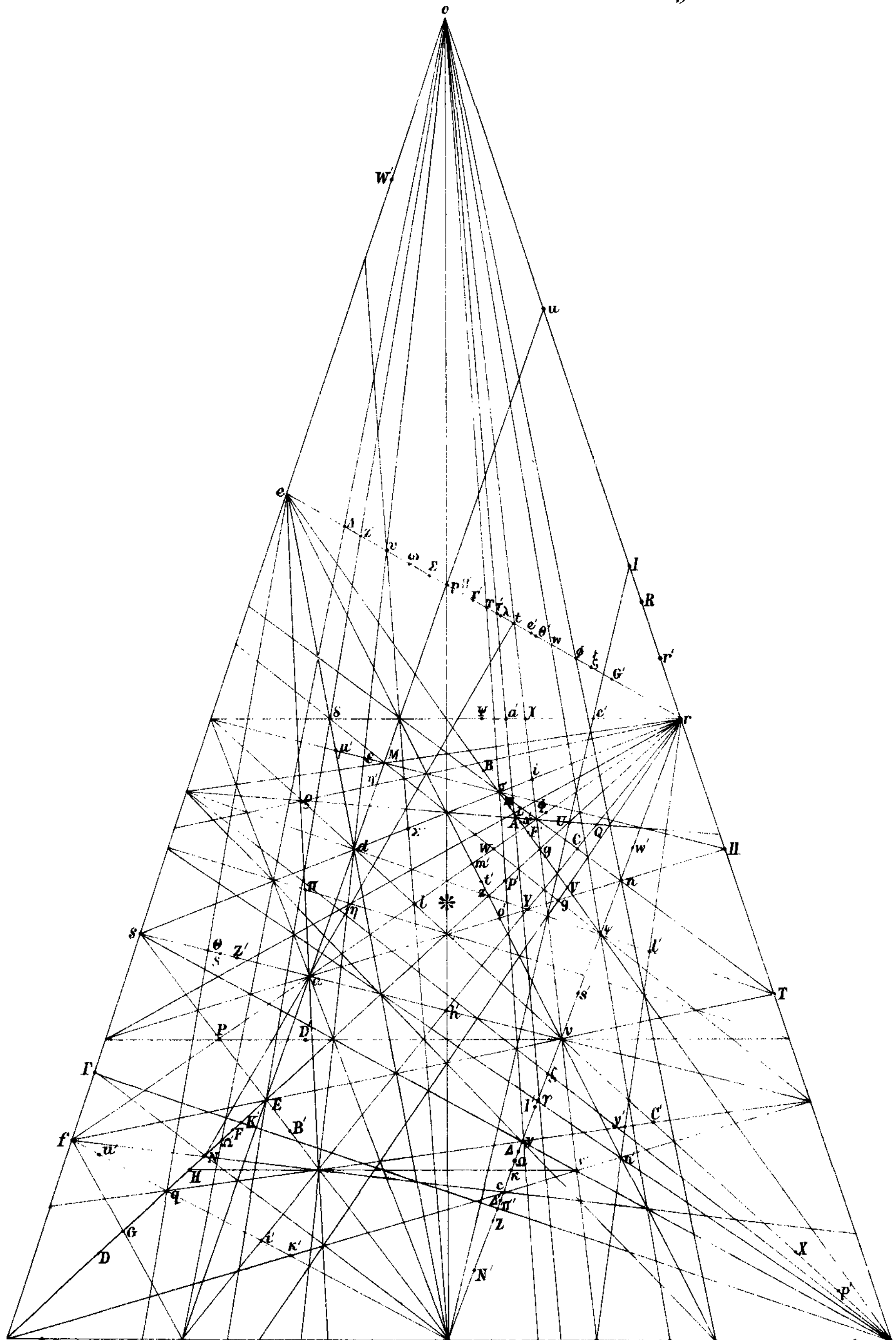

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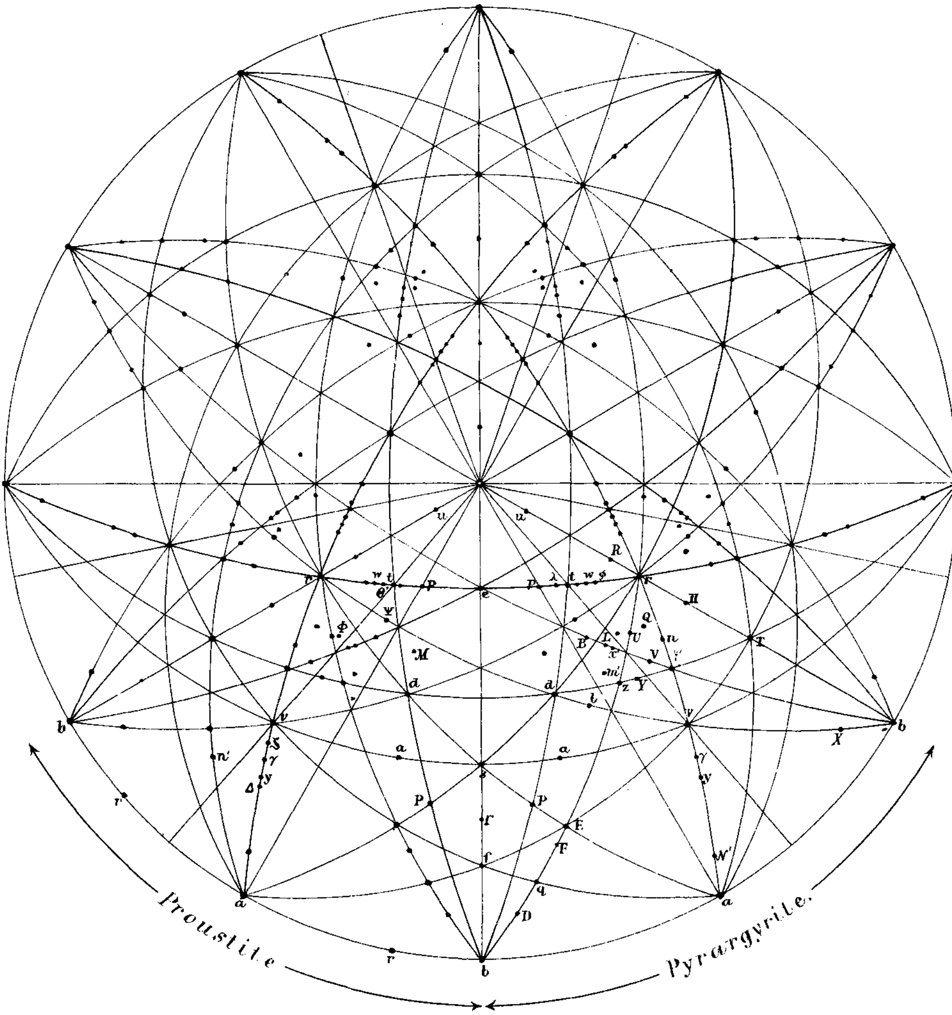

Typical Forms.

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