

Notes on some Bolivian minerals (Jamesonite, Andorite, Cassiterite, Tourmaline, &c.).

By L. J. SPENCER, M.A., F.G.S.

With chemical analyses by G. T. PRIOR, M.A., D.Sc., F.G.S.
Assistants in the Mineral Department of the British Museum.

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DURING the last twelve years I have communicated to this Society, often in collaboration with Dr. G. T. Prior, several papers descriptive of Bolivian minerals. These papers have dealt primarily with the species augelite, andorite, argyrodite, stannite, and chalcostibite, though many others have been examined and in some cases incidentally mentioned. The latter, as being of lesser general interest, or as not having led to sufficiently important results for separate publication, are now collected together in the present notes.

The material available for examination has been acquired for the British Museum collection from various sources, and mainly during the last few years. Special mention may be made of several lots of specimens sent, at various times since 1894, for examination, and presented to the Museum by my friend Mr. Malcolm Roberts, A.R.S.M., a mine manager in Bolivia. Another collection, which may be specially mentioned, was brought from Bolivia by Sir Martin Conway, and presented by him in 1899 to the British Museum. A few choice specimens, notably a mass of pyrargyrite with crystals of argyrodite from Colquechaca, and a large mamillated mass of native copper coated with native silver from the Cobrizos mine at San Cristobal in province Nor-Lipez, have been presented by Señor F. Avelino Aramayo, formerly the Bolivian Minister in London. Thanks are also due to Mr. Thomas J. Hooper, General Manager to the Compañía Minera de Oruro, for a very large and magnificent specimen of andorite. Still more recently, several Bolivian specimens have been selected from the private collection of the late Theodor Hohmann (1843–1897), a mining engineer in Chili¹.

The specimens sent by Mr. Roberts are mainly from the silver mines at Tatasi and Portugaleta in the province Sud-Chichas, and from the tin and bismuth mines at Tasna in province Nor-Chichas, department Potosi. From his own observation and from my notes on the specimens, Mr. Roberts² has published a brief account of the mineral-species which he has found at the former locality.

Sir Martin Conway's specimens are mostly from the silver and tin mines at Oruro, and from a tin and bismuth mine on the mountain of Huaina Potosi, near La Paz. A description of the twenty-three mineral-species represented in this collection of forty-six specimens has already been given³ in some detail in the narrative of Sir Martin Conway's expedition; from this source such points as appear to be of general mineralogical interest are incorporated in the present notes.

¹ A brief description of this collection has been given by R. Pöhlmann, 'Die Mineralien-Sammlung des † Theodor Hohmann.' Verh. Deutsch. wiss. Ver. Santiago de Chile, 1899, vol. iv, pp. 75–86.

² M. Roberts, 'Minerals found in the silver lodes of Tatasi and Portugaleta, Bolivia.' Trans. Inst. Mining and Metallurgy, London, 1899, vol. vii, pp. 91–3.

³ L. J. Spencer, 'A description of the mineral specimens brought from Bolivia by Sir W. Martin Conway.' Pp. 343–66 in Sir Martin Conway, 'The Bolivian Andes, a record of climbing and exploration in the Cordillera Real in the years 1898 and 1900.' Harper & Brothers, London and New York, 1901.

The appendix of this volume also includes notes on other natural history specimens—the rock specimens were described by Professor T. G. Bonney (pp. 366–86)—but unfortunately there are no indications on the title-page nor

1. ANALYSIS OF CRYSTALLIZED JAMESONITE¹.

The specimens (Brit. Mus. nos. 80934, 83057, 83058) to be described are from the Cerro de Ubina², situated to the east of Huanchaca, and in the province Porco of the department Potosi. Tufts of jamesonite needles are disposed in the spaces between iron-pyrites crystals, which are present as veins in the massive, fibrous and radiating jamesonite forming the bulk of specimens. These veins of iron-pyrites consist of a granular aggregate of crystals interfering with each other's growth, and are of two kinds. The larger veins consist of fairly large and bright octahedra with small planes of the cube and pentagonal dodecahedron e {210}; it is in cavities between these crystals of iron-pyrites that most of the jamesonite needles are developed. The other veins are much narrower and consist of small cubes of iron-pyrites with small planes of the octahedron and e {210}. Imbedded in the massive jamesonite are patches of argentiferous tetrahedrite, and in cavities one or two minute crystals of native sulphur.

The needles of jamesonite reach a length of $\frac{1}{2}$ cm. and a thickness of $\frac{1}{2}$ mm.; they are deeply striated parallel to their length, and are usually closely aggregated. They are iron-black with a bright metallic lustre, and sometimes a slight iridescent tarnish. The streak is black and dull or in part shining; the hardness is $2\frac{1}{2}$. The needles are very brittle; they do not bend, but break along surfaces of good cleavage³ perpendicular to their length.

Nineteen crystals were placed on the goniometer, but no really good measurements were obtained. The predominating form is the prism m {110}, and the needles have a rhomb-shaped cross-section; though sometimes one pair of parallel prism-faces is more largely developed and the crystals are then lath-shaped. Narrow faces of the forms n {120}, b {010}, and a {100} were also sometimes observed, but no terminal planes.

in the index of their existence. Figs. 1, 2, 3, and 10 in the present paper are reproduced from Sir Martin Conway's book, the electrotypes having been kindly supplied by the publishers.

¹ Compare this vol., p. 207.

² This occurrence has already been mentioned by A. Frenzel (*Neues Jahrb. Min.*, 1893, vol. ii, p. 126). Here the locality is given incorrectly as 'Cerro de Uleina'.

³ The statement of the cleavages of jamesonite given in the textbooks dates back to F. Mohs (1824). The basal cleavage, c {001}, though good, can scarcely be described as perfect, and the others, m {110} and b {010}, probably do not exist. The latter were not to be observed on any of the jamesonites I have examined; any apparent cleavage in these directions can be explained by the parallel aggregation of the acicular crystals.

	Limits.	No. of edges.	Mean.	Calcd.
$mm''' = 110:1\bar{1}0$	$\left\{ \begin{array}{l} 78^\circ 10' - 79^\circ 1' \\ 77^\circ 32' - 81^\circ \end{array} \right.$	$\left. \begin{array}{l} 4 \text{ (best)} \\ 23 \text{ (all)} \end{array} \right\}$	$\left. \begin{array}{l} 78^\circ 39' \\ 79 \quad 1 \end{array} \right\}$	$78^\circ 38'$
$mm' = 110:\bar{1}10$	$\left\{ \begin{array}{l} 101^\circ 10' - 102^\circ 6' \\ 100^\circ \quad - 103^\circ \end{array} \right.$	$\left. \begin{array}{l} 4 \text{ (best)} \\ 21 \text{ (all)} \end{array} \right\}$	$\left. \begin{array}{l} 101 \quad 23 \\ 101 \quad 16 \end{array} \right\}$	$101 \quad 22$
$mn = 110:120$	$17^\circ \quad - 22^\circ$	4	$19\frac{1}{2}^\circ$	19 17
$mb = 110:010$	$49^\circ \quad - 51\frac{1}{2}^\circ$	5	50 24	50 41
$m:c$ (cleavage)	$85^\circ \quad - 94^\circ 52'$	14	89 49	90 0

The means, $78^\circ 39'$ and $78^\circ 37'$ ($=180^\circ - 101^\circ 23'$) of the best readings, give the value for $mm''' = 110:110$ as $78^\circ 38'$, which agrees closely with Haidinger's determination¹ of $78^\circ 40'$ on needles of jamesonite from Cornwall. The axial ratio corresponding with this angle, $78^\circ 38'$, is $a:b = 1:0.819$.

Two lots of material were collected for quantitative analysis. One lot consisted of isolated needles, many of which had been measured on the goniometer, together with some aggregates of needles taken from the cavities between the iron-pyrites crystals. The other lot was of massive material consisting of a more or less parallel aggregate of fibres, and showing a good end-cleavage. When examined under the microscope no impurities, such as iron-pyrites, could be detected. The method of analysis was the same as that previously adopted for andorite², and the following results, I for the crystals and II for the massive material, were obtained by Dr. G. T. Prior:—

	I.	Atomic ratios.		II.	Atomic ratios.			
S ...	20.52	0.6447	17.85	21.37	0.6714	18.50		
Sb ...	34.53	0.2889	8.00	34.70	0.2903	8.00		
Pb ...	41.18	0.2005	5.55	40.08	0.1952	5.38	} 6.88	
Fe ...	2.76	0.0496	1.37	7.03	2.79	0.0502		1.38
Cu ...	0.26	0.0041	0.11	0.22	0.0035	0.09		
Ag ...	0.01	0.0001	—	0.13	0.0012	0.03		
	<hr/>			<hr/>				
	99.26			99.29				
Sp. gr.	5.519			5.546				
Weight used	0.3932 gram			0.8997 gram				

English translation of F. Mohs's 'Treatise of Mineralogy', Edinburgh, 1825, vol. iii, p. 26; Edinburgh Journ. Sci., 1825, vol. ii, p. 374. The manuscript catalogue of the Allan collection, now in the British Museum, gives, under date 1824, this angle as $78^\circ 30'$, the entry referring to acicular Cornish crystals. The axial ratio corresponding with Haidinger's angle is erroneously given in the textbooks as $a:b = 1:0.915$.

² Min. Mag., 1897, vol. xi, p. 290.

The second of these analyses is the more reliable: in the first the lead sulphate included a little basic iron sulphate, and there may possibly have been a slight loss of sulphur.

These analyses do not lead to any simple formula. They correspond fairly closely with $7(\text{Pb}_{4/5}, \text{Fe}_{1/5})\text{S} \cdot 4\text{Sb}_2\text{S}_3 = \text{R}_7''\text{Sb}_8\text{S}_{13}$, the calculated percentage composition of which is given below:—

		$7(\text{Pb}_{4/5}, \text{Fe}_{1/5})\text{S} \cdot 4\text{PbS} \cdot 4\text{Sb}_2\text{S}_3$	$4\text{PbS} \cdot 3\text{Sb}_2\text{S}_3$	$3\text{PbS} \cdot 2\text{Sb}_2\text{S}_3$	$7\text{PbS} \cdot 4\text{Sb}_2\text{S}_3$	$2\text{PbS} \cdot \text{Sb}_2\text{S}_3$
S	...	21.68	21.20	20.75	20.17	19.68
Sb	...	34.29	36.73	34.63	31.89	29.55
Pb	...	41.24	42.07	44.62	47.94	50.77
Fe	...	2.79	—	—	—	—
		100.00	100.00	100.00	100.00	100.00

The large amount of iron, which presents a difficulty in deducing a satisfactory formula, is not present as iron-pyrites, as the mode of occurrence of the mineral might suggest, since the amount of sulphur shown in the analyses is scarcely sufficient even for monosulphide. The atomic amount of sulphur required for Sb_2S_3 , PbS , FeS , and CuS is 0.6855 in the second analysis, whilst the amount found is 0.6714. If the iron and copper are left out of account, the formula becomes $4\text{PbS} \cdot 3\text{Sb}_2\text{S}_3 = \text{Pb}_4\text{Sb}_6\text{S}_{13}$. As shown also by earlier analyses, quoted below, the iron appears, however, to be present in all cases to the amount of 2 to 3 per cent.

The observations recorded above were made in 1897, and their publication has been delayed in the hope of other material being found which would help to decide the question of the chemical formula of jamesonite, but, as yet, the material here described is the best available.

Several analyses have been published under the name jamesonite; but it must be remembered that many of these have been made on impure, massive material and ores, solely with the object of giving a specific mineralogical name; and that, in some cases, to make the results agree with the textbook formula, $2\text{PbS} \cdot \text{Sb}_2\text{S}_3$, certain amounts of impurities (iron-pyrites, galena, stibnite) have been assumed to be present and have been deducted. Only those analyses which have been made on material known to be jamesonite by the presence of the basal cleavage can be of any value in deducing a formula for this mineral: such analyses are collected together below.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
S	22.15	22.53	[23.01]	21.78	21.52	20.86	21.35	21.75
Sb	34.40	34.90	33.47	32.62	33.03	31.94	not det.	32.00
Pb	40.75	39.45	40.35	39.97	40.13	42.79	40.47	39.05
Fe	2.30	2.65	2.96	3.63	not det.	2.83	2.68	2.00
Cu	0.13	0.19	0.21	—	—	1.01	0.50	3.45
Zn	—	—	—	0.42	0.36	1.84	5.82	0.62
	<u>99.73</u>	<u>99.72</u>	<u>100.00</u>	<u>99.48</u> ¹	<u>—</u>	<u>101.27</u>	<u>—</u>	<u>100.41</u> ²
Sp. gr.	—	—	—	5.616		5.478-5719		5.54

I-III. H. Rose (Ann. Chem. Phys. (Poggendorff), 1826, vol. viii, p. 100; 1829, vol. xv, p. 470). Cornwall.

IV and V. F. Schaffgotsch (ibid., 1836, vol. xxxviii, p. 403). Valencia de Alcantara, Spain. V, the mean of three partial analyses.

VI and VII. C. Rammelsberg (C. Rammelsberg and C. Zincken, ibid., 1849, vol. lxxvii, p. 242). Selkethal, Harz. Different figures are given in Rammelsberg's Min.-Chem., 1860, p. 71; 1875, p. 92.

VIII. M. Siewert (A. W. Stelzner, Min. Petr. Mitt. (Tschermak), 1873, p. 247). Sierra de los Angulos, Argentina.

These, then, are the only analyses that can be given for what is certainly known to be jamesonite, and one of the analyses now published is the only one that has been made on measured crystals of this mineral.

Rose's analyses show a slight excess³ of sulphur over that required for RS and Sb₂S₃; he consequently deducted the iron as iron-pyrites and deduced the formula 3PbS.2Sb₂S₃. Schaffgotsch, to make his analyses agree with this formula, had to deduct 8½ per cent. of impurities (ZnS, Bi₂S₃, FeS); there being no excess of sulphur, the iron was assumed to be present as pyrrhotite. Rammelsberg deducted from his analysis (VI) FeS₂, ZnS, and 6 per cent. of Sb₂S₃, and gave the formula 2PbS.Sb₂S₃. Stelzner, although he mentions that the material analysed was apparently pure, also deducted iron (as mispickel, iron-pyrites, and copper-pyrites), and deduced the formula 37PbS.AgS.CuS.26Sb₂S₃.

All these analyses show the presence of about 2 to 3 per cent. of iron,

¹ Including Bi 1.06.

² Including Ag 1.34, As 0.20.

³ The excess is, however, not sufficient for iron-pyrites.

and taking this into account, they agree fairly well with the formula $7(\text{Pb}_2, \text{Fe}_1)\text{S}_4\text{Sb}_2\text{S}_3$, suggested above.

Sulphantimonites of lead are of frequent occurrence in Bolivia and have often been referred to jamesonite, but only rarely have they been definitely determined to belong to this species. In the account of Sir Martin Conway's collection I have described ¹ specimens of crystallized jamesonite from Oruro, Bolivia; these were determined by measurement of the prism-angle (about 79°) and by the presence of a good basal cleavage. Other specimens, previously referred to zinckenite², have since been shown by these characters to be jamesonite: they are from Machacamarcá near Potosí and from the Socavón de la Virgen at Oruro.

2. SEMSEYITE FROM URURO.

The specimen here described was sent to me by the Foote Mineral Company, of Philadelphia, for determination. The crystals of semseyite are iron-black in colour and have a bright metallic lustre. They are aggregated in rosette-like groups, so that the individual crystals, which reach to 5 mm. across, are not very distinctly developed. The faces of the twisted crystals are so curved and irregular, with step-like and drusy growths, that it was impossible to obtain any reliable measurements of the angles between them. In general habit and appearance, however, the crystals are exactly like those of pligionite and semseyite from Wolfsberg in the Harz. The basal plane $c\{001\}$ and the pyramid $n\{111\}$ can be distinguished, and parallel to the faces of the latter there are good cleavages. Measurement of several of the most likely crystals gave results varying between 40° and 45° for the angle between c and n . These measurements are not sufficient to distinguish between pligionite and semseyite, since in the former $cn=41^\circ 8'$ and in the latter $cn=46^\circ 35'$ ³.

In order to determine to which member (pligionite, heteromorphite or semseyite) of the pligionite group of minerals the crystals belong, it therefore became necessary to determine their specific gravity and the percentage of lead they contain. A small amount (0.16 gram) of the crystallized material was collected, and was analysed by Dr. G. T. Prior with the following results:—

¹ Loc. cit., p. 359.

² Min. Mag., 1895, vol. xi, p. 23; 1897, vol. xi, p. 299.

³ Min. Mag., 1899, vol. xii, p. 55.

		Atomic ratios.
Pb . . .	52.9 . . .	0.256
Ag . . .	1.6 . . .	0.015
Sb . . .	24.8 . . .	0.206
S . . .	18.7 . . .	0.583
		98.0
Sp. gr. . .	5.82	

These results point conclusively to semseyite¹. The presence of silver is noteworthy, since this element has not previously been detected in minerals of the pligionite group. It is possible, however, that the silver may be present as andorite intermixed with the semseyite, although no andorite could be detected on the specimen. Another point brought out by the analysis is that the mineral is rather more basic than the two semseyites previously analysed: here, (Pb, Ag)₂:Sb=1.28:1; whilst in semseyite from Hungary and the Harz, Pb:Sb=1.15:1 and 1.05:1 respectively.

The matrix of the specimen consists of another species of sulphantimonite of lead, the structure of which is fibrous. The compact aggregation of fibres, which are either radially or confusedly arranged, is mixed with some massive iron-pyrites and a little kaolin. On the free surface of the specimen the fibres have the form of delicate, flexible hairs, which can be bent without being broken, and are therefore *plumosite*². The surface of this felted mass of plumosite needles is curiously marked with smooth, concave depressions, rather suggesting that the mineral had been partly dissolved. The semseyite crystals occur only on this surface and are partly embedded in the feathery plumosite. With them is a little galena, which often forms the nucleus of the rosettes of semseyite crystals.

Although sulphantimonites of lead are of common occurrence in Bolivia, they appear to belong usually to the fibrous, orthorhombic species, especially jamesonite and plumosite; and none of the monoclinic species of the pligionite group have been hitherto determined from this region. It is possible that one or more of the eight varieties of 'antimonial galena' mentioned by D. Forbes³ from the department of La Paz may belong to the pligionite group, but his descriptions are too brief to enable one to judge of this.

¹ Compare the table of analyses and sp. gr. given in *Min. Mag.*, vol. xii, p. 65.

² Compare this vol., p. 207.

³ *Phil. Mag.*, 1865, ser. 4, vol. xxix, p. 10. In an earlier paper (*Quart. Journ. Geol. Soc.*, 1861, vol. xvii, p. 61) Forbes gives the name pligionite in a list of minerals occurring in the Bolivian mineral-veins.

Semseyite has previously been recorded only from Felsöbánya and Rodna in Hungary and from Wolfsberg in the Harz.

3. NEW CRYSTAL-FORMS ON ANDORITE¹.

Andorite is, at present, known from only two localities, namely, Felsöbánya in Hungary and Oruro in Bolivia. At the latter it seems to be rather plentiful, and there are now several specimens representing this occurrence in the British Museum collection. Crystals were detected on four of the specimens from Oruro presented by Sir Martin Conway; and the following description is based mainly on that specimen on which the best crystals of stannite² were found.

This specimen (Brit. Mus. no. 84686), from the San José mine at Oruro, consists of groups of radiating, prismatic crystals of mispickel, encrusted with crystals of andorite, stannite, and iron-pyrites. The bright crystals of andorite are sometimes doubly terminated, and the largest is about 4 mm. long. In habit they are somewhat tabular parallel to the macropinacoid $a\{100\}$. Pyramids and domes are numerous, but are very irregularly developed, so that the crystals are usually distorted and unsymmetrical in appearance. In figs. 1 and 2 the crystals are idealized by drawing all the faces of the same form of equal size.

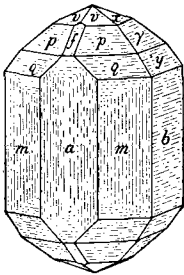


Fig. 1.

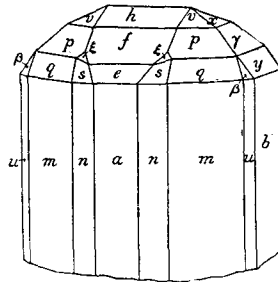


Fig. 2.

Andorite from Oruro, Bolivia.

A conspicuous feature of the crystals is the deep striation of all the faces (fig. 1); in some zones the striations are often so deep and numerous as to render the crystal almost unsuitable for measurement. The pyramids, domes, the brachypinacoid $b\{010\}$, and the prisms $u\{130\}$, $g\{250\}$, and $k\{120\}$ are all striated horizontally; the macro-

¹ Compare Min. Mag., 1897, vol. xi, p. 286.

² Min. Mag., 1901, vol. xiii, p. 55.

pinacoid $a\{100\}$ and the remaining prisms are striated vertically, with a few horizontal striae, especially on $a\{100\}$, giving rise to rectangular markings. On the goniometer, these striated zones give continuous bands of reflected images, limited, however, between certain points: in the prism-zone between $a\{100\}$ and $l\{230\}$; in the macrodome-zone between $a\{100\}$ and $h\{102\}$; in the brachydome-zone between $b\{010\}$ and $x\{011\}$ or $w\{035\}$; and in the several pyramid-zones $[hk0, 001]$ the bands are limited between the zones $[100, 010]$ and $[102, 010]$. As the summit of a crystal is approached, the striations become less numerous and the bands of reflected light much fainter. The pyramid-zones showing such bands of light are:— $[310, 001]$, $[210, 001]$, $[110, 001]$, $[230, 001]$, $[120, 001]$, and $[130, 001]$; of these it may be remarked that no pyramidal faces have yet been recorded in the zone $[230, 001]$.

Three crystals were measured on the goniometer, and the following thirty-five forms noted:—

Pinacoids: $a\{100\}$ $b\{010\}$ $c\{001\}$.
 Prisms: $n\{210\}$ $m\{110\}$ $l\{230\}$ $k\{120\}$ $g\{250\}$ $u\{130\}$.
 Macrodomes: $h\{102\}$ $\sigma\{203\}$ $f\{101\}$ $e\{302\}$.
 Brachydomes: $w\{035\}$ $x\{011\}$ $\gamma\{021\}$ $y\{031\}$ $\eta\{041\}$.
 Pyramids: $\xi\{312\}$ $s\{211\}$ $A\{321\}$ $v\{112\}$ $C\{243\}$? $\omega\{132\}$
 $\chi\{223\}$ $\delta\{364\}$ $\beta\{131\}$
 $p\{111\}$ $r\{121\}$ $E\{261\}$.
 $q\{221\}$ $\epsilon\{362\}$
 $\rho\{331\}$ $D\{241\}$
 $B\{441\}$

The forms present on each crystal were:—

No. 1. ab , $nmlkqu$, $x\gamma y$, s , $q\beta B$, ϵD , βE ; also deeply striated, indefinite macrodomes.

No. 2. abc , $nmlu$, $wxy\eta$, s , $v\chi\rho q\beta B$, $\delta\epsilon$; also indefinite macrodomes.

No. 3. abc , $nmlku$, $h\sigma f e$, $x\gamma$, ξ , s , A , $v\chi\rho q\beta B$, Cr , $\omega\beta$.

The basal plane, $c\{001\}$, is present on crystal No. 2 as a very small face truncating the brachydomes, and it is faintly curved and striated parallel to the brachyaxis $[100]$; on crystal No. 3 it truncates the macrodomes, and is curved and striated parallel to $[010]$.

Of the forms given above, $u\{130\}$ has not before been observed on Bolivian crystals, and $g\{250\}$ has been observed only by Brügger. The following are new for the mineral:—

$w\{035\}$. Two narrow, bright faces, faintly striated horizontally.

$\eta\{041\}$. Only as bright striae; observed twice.

- $\xi\{312\}$. Two small bright faces striated horizontally; in the zones [112, 100], [101, 110], [302, 010], and [310, 001]¹.
- $A\{321\}$. Two narrow planes on the edges of the horizontal striae on $a(100)$; in the zones [101, 110], [100, 021], and [320, 001]¹.
- $B\{441\}$. Small planes, sometimes rather wide; deeply striated horizontally. On all three crystals.
- $C\{243\}$?. Two small planes in the striated zones [120, 001]; the brightest portion of the bands fall just on either side of the zone [203, 010].
- $D\{241\}$. A fairly large plane, deeply striated horizontally; in the zones [120, 001] and [211, 010].
- $E\{261\}$. A small plane deeply striated horizontally and giving no bright image in the reflected band of light; in the zones [130, 001] and [211, 010].

The following are the angular measurements establishing the new forms:—

	Calculated.	Measured.
$wb, 085 : 010$	$75^\circ 11\frac{1}{2}'$	$74^\circ 22', 75^\circ$
$\eta b, 041 : 010$	$29\ 17$	$30^\circ, 29\frac{1}{2}^\circ$
$\xi e, 312 : 302$	$9\ 0\frac{1}{2}$	$9^\circ 7'$
$\xi a, 312 : 100$	$46\ 3$	46°
$312 : (310)^1$	$44\ 39$	$44^\circ 42'$
$Aa, 321 : 100$	$34\ 9$	$34^\circ 1'$
$321 : (320)^1$	$24\ 46$	$24^\circ, 25^\circ$
$Bm, 441 : 110$	$17\ 27$	$17^\circ 38', 17^\circ 18', 18^\circ 8', 17^\circ 24'$
$Dk, 241 : 120$	$24\ 17$	24°
$241 : (201)^1$	$47\ 10$	$47^\circ 16'$
$261 : (201)^1$	$58\ 16\frac{1}{2}$	$58^\circ 28'$

On a second specimen (no. 84685), also from the San José mine at Oruro, are several small crystals of andorite encrusting the walls of cavities in massive argentiferous tetrahedrite. It is possible that some of the massive material is actually andorite since it closely resembles the crystallized material in appearance. All the fragments tested, however, contained copper, but the crystals when treated with nitric acid on a microscope-slide showed no indications of the presence of copper. The crystals are 1–2 mm. in length, and are bright, but

¹ The faces (310), (320), and (201) were not present on the crystals, but their positions were fixed approximately by means of rough graduations on the crystal adjustment arcs of the goniometer.

deeply striated in the manner described above. On one crystal, pyramid-planes were noticed in each of the eight octants. The forms determined by the goniometrical measurement of one crystal were:—*abc, nml, hfe, π{082}γγ, vpg.*

Mention may here be made of a magnificent specimen (no. 84659) of andorite presented to the British Museum in 1899 by Mr. Thomas J. Hooper, General Manager of the Compañía Minera de Oruro. This is from the Itos Atocha mine at Oruro; it measures roughly $30 \times 25 \times 7$ cm. and weighs $48\frac{1}{2}$ pounds. It formed part of a vein of iron-pyrites, which mineral is frequently crystallized in bright cubo-octahedra with small planes of the pentagonal dodecahedron $e\{210\}$. On this iron-pyrites, in cavities and on the surface, is deposited the andorite, numerous large crystals of which cover the whole face of the vein, or free crystallized surface of the specimen. The cubo-octahedra of iron-pyrites and the crystals of andorite on this surface are much corroded, and deposited on them, as a later growth, are one or two small cubes of iron-pyrites and a few small groups of flexible hairs of plumosite. On the back of the specimen is some pale yellowish clay.

The large crystals of andorite on the front of the specimen average one centimetre in length, but reach a length of two centimetres or more: they are of the habit shown in fig. 1 in vol. xi, p. 294 of this magazine, with deeply striated prisms and a brachydome. The faces of the brachydome are specially deeply etched, and from the pits and grooves light is reflected from minute faces parallel to the brachypinacoid and a pyramid. These crystals are too large and rough for measurement, but a small bright crystal from a cavity at the back of the specimen was found for this purpose; this crystal, on which the pyramid-planes were largely developed, showed the following forms:—*ab, nmkqu, xyy, s, pqr, dr, ωβ.*

On another noteworthy specimen from Oruro, the several large crystals of andorite measure $2 \times 1.5 \times 0.5$ cm.; they are flattened prisms (tabular parallel to the macropinacoid) with numerous well-developed terminal planes.

Note on the Systematic Position of Andorite.

In the textbooks andorite has usually been placed in the chalcostibite group, and considered to be an argentiferous zinckenite. This, however, is incorrect, as will be shown below.

The parameters given by Professor P. von Groth¹ are arrived at as follows:—

Andorite (Brögger),	$a : b : c = 0.6771 : 1 : 0.4458$
Andorite (Groth),	$\frac{3}{8}a : c : \frac{1}{4}b = 0.5696 : 1 : 0.5608$
Chalcostibite,	$a : b : c = 0.5312 : 1 : 0.6395$

Although Groth's parameters for andorite and chalcostibite differ only in the second place of decimals, yet when the corresponding angles are compared it is seen that between one pair there is a difference of nearly 6°.

Andorite,	$100 : 808 = 29^\circ 40'$,	$010 : 230 = 44^\circ 33'$,	$010 : 041 = 29^\circ 17'$.
Chalcostibite,	$100 : 110 = 27^\circ 59'$,	$001 : 101 = 50^\circ 17'$,	$001 : 011 = 32^\circ 36'$.

By placing an orthorhombic crystal in one or other of the six possible positions and selecting a suitable parametral plane, it is possible to obtain an apparent agreement in the parametral ratios of any two orthorhombic minerals. Brögger's comparison of the parameters of andorite ('sundtite') and aeschnyite is, indeed, closer than Groth's comparison of andorite and chalcostibite. Groth's parametral plane for andorite would be Brögger's (8.12.3), but this is not developed on the crystals, which are exceptionally rich in pyramidal planes.

Consequent upon the assumption that andorite is an isomorphous member of the chalcostibite group, Groth considers it to be an argentiferous zinckenite with the formula $(\text{Pb, Ag}_2)\text{Sb}_3\text{S}_4$, indicating that lead and silver may replace each other in indefinite proportions. There can be little doubt, however, that andorite is really a double salt with the definite formula $2(\text{PbS.Sb}_2\text{S}_3).(\text{Ag}_2\text{S.Sb}_2\text{S}_3) = \text{PbAgSb}_3\text{S}_6$. The four analyses, made independently on material from two localities, all approximate to this formula, as does also an analysis of stannite containing 8.58 per cent. of admixed andorite². The following are the atomic ratios derived from these four analyses:—

	Pb	: Ag ³	: Sb	: S.
Loczka, 1892	0.880	: 0.945	: 2.867	: 6
Mann, 1894	1.004	: 0.900	: 2.896	: 6
Prior, 1897	0.923	: 1.042	: 3.002	: 6
„ „	1.013	: 0.975	: 2.990	: 6

In any discussion of these analytical results the following points must

¹ P. von Groth. 'Tabell. Uebers. d. Mineralien,' 1898, 4th edition, pp. 32-3. The parameters (0.5747 : 1 : 0.5618) actually given by Groth are based on the less accurate measurements of Krenner. Groth incorrectly states that andorite has a perfect cleavage; there is no cleavage.

² Min. Mag., 1901, vol. xiii, p. 61.

³ With silver is included 0.65 to 0.73 per cent. of copper. Copper minerals were not found on any of the specimens used for analysis.

be borne in mind:—(1) There is no statement of the quantity and quality of the material analysed by Loczka. (2) Mann made three analyses of material from the same specimen, one portion being andorite ('webnerite'), another consisting of needles referred to zinckenite, while the third was a mixture of these two minerals; but it is to be remarked that the third analysis is not intermediate between the two others, so there must be some error. (3) Prior's first analysis was made on only a small amount (0.2073 gram) of material not of ideal quality. (4) His second analysis, made on half a gram of pure crystals, is no doubt the most reliable of all the four analyses, and it is the one which agrees most closely with the formula proposed.

The meta-sulphantimonites of lead and silver crystallize in three distinct forms, viz. :—

1. Zinckenite, the orthorhombic lead salt, PbSb_2S_4 , sometimes containing a fraction of a per cent. of silver. (In the isomorphous group, including chalcostibite, sartorite, and emplectite, no silver salt is known.)
2. Andorite, the double salt, $\text{PbAgSb}_3\text{S}_6$, also orthorhombic, but with no other crystallographic relation to zinckenite. (This does not fall into any isomorphous group.)
3. Miargyrite, the monoclinic silver salt, AgSbS_2 , sometimes containing one or two per cent. of lead. (Lorandite, TlAsS_2 , is probably isomorphous with this, but no corresponding lead salt is known.)

The relation which exists between these three minerals is exactly the same as in certain well-known cases¹ amongst artificial salts, where we have an isodimorphous (or more correctly a crypto-isodimorphous) pair of simple salts with a double salt. Thus, potassium nitrate and silver nitrate form three kinds of crystals :—

1. Orthorhombic KNO_3 , with very little AgNO_3 .
2. Monoclinic $\text{KAg}(\text{NO}_3)_2$; a double salt.
3. Orthorhombic AgNO_3 , with very little KNO_3 .

A similar case among minerals is supplied by calcite, barytocalcite (CaBaC_2O_6), and witherite.

A series of quite another kind in which andorite may also be placed is, as I have already pointed out², the morphotropic series formed by this mineral with the double (silver-lead) salts diaphorite and freiesle-

¹ See, e. g., Professor Miers's 'Mineralogy', 1902, p. 231.

² Amer. Journ. Sci., 1898, ser. 4, vol. vi, p. 316.

benite. These three minerals resemble each other so closely in appearance, that, as a rule, they can only be distinguished by measurement of the crystals. In all there is a prism of very nearly 90° , and taking this prism to be {110} the axial ratios, as usually accepted, become:—

		Chem. comp.	Sp.gr.
Andorite,	$\frac{3}{2} a : b : c = 1.0157 : 1 : 0.4458$	RS.Sb ₂ S ₃	5.35
Diaphorite,	$2 a : b : c = 0.9839 : 1 : 0.7345$	2RS.Sb ₂ S ₃ ?	6.0
Freieslebenite,	$\frac{4}{3} a : b : c = 0.9786 : 1 : 0.9277$	2 $\frac{1}{2}$ RS.Sb ₂ S ₃	6.3

In this series, increased basicity is accompanied by an increase in length of the vertical crystallographic axis, the vertical axes being in the ratio of approximately 3 : 5 : 6. This is the same kind of relation as that existing between the minerals humite, chondrodite, and clinohumite, and between plagionite, heteromorphite, and semseyite¹.

4. CHALCOSTIBITE FROM URURO.

Two specimens of this orthorhombic sulphantimonite of copper (CuSbS₂) have recently been described from the Pulacayo mine, Huanchaca, Bolivia². The crystals now to be described are from Oruro, which is a new locality for this rare mineral³.

One (no. 84687) of the two specimens is that described under augelite (p. 323). The other (no. 84684), from the San José mine at Oruro, has been referred to under stannite⁴. Associated minerals are andorite, stannite, quartz, iron-pyrites, &c. The bright, tabular or blade-shaped crystals of chalcostibite occur in cavities in massive tetrahedrite, and are usually only of small size, rarely reaching 1 cm. in length and breadth. They are of a steel-grey colour, and have a brilliant metallic lustre. Parallel to the direction of the perfect cleavage, *c*(001), they are tabular in form, and in the direction of the macro-axis are

¹ Min. Mag., 1899, vol. xii, p. 66.

² S. L. Penfield and A. Frenzel. 'On the identity of chalcostibite (wolfsbergite) and guejarite, and on chalcostibite from Huanchaca, Bolivia.' Amer. Journ. Sci., 1897, ser. 4, vol. iv, p. 27; Zeits. Kryst. Min., 1897, vol. xxviii, p. 598; abstract Min. Mag., 1897, vol. xi, p. 338.

³ The locality, Machacamarcá, Bolivia, given in C. F. Naumann's 'Elem. d. Min.' (14th edit. by F. Zirkel, 1901, p. 451) and in C. Hintze's 'Handb. d. Min.' (1902, vol. i, p. 996), is based on F. von Sandberger's determination of 'guejarite' (Neues Jahrb. Min., 1886, vol. i, p. 89); Sandberger, however, specially states that the mineral was not chalcostibite (with which 'guejarite' has since been proved to be identical). Compare Min. Mag., 1895, vol. xi, p. 23, and p. 314, above.

⁴ Min. Mag., 1901, vol. xiii, p. 64.

deeply striated. Terminal pyramidal planes are not always to be seen, and when present are usually small and irregularly developed. Though somewhat dull they give good images of the goniometer-signal, and, as is usually the case with this mineral, they have high indices.

The following forms were noted on the three crystals measured. The angles observed were in close agreement with those given by Penfield.

No. 1. $c\{001\}$, $d\{101\}$, $g\{201\}$, $q\{863\}$, $p\{6.12.7\}$. The planes p are largely developed, and the crystal closely resembles Penfield's fig. 2 (loc. cit.).

No. 2. $c\{001\}$, $\Delta_2\{103\}$, $d\{101\}$, $g\{201\}$.

No. 3. $c\{001\}$, $d\{101\}$, $g\{201\}$, $t\{021\}$, $s\{065\}$, $q\{863\}$, $\tau\{261\}$; and other small pyramids not determined, one being in the zone $[cr]$ and having the indices $\{6.18.1\}$ or $\{7.21.1\}$. Measured to c 86° and $86^\circ 55'$. Calculated $c:(7.21.1)=86^\circ 23\frac{1}{2}'$, $c:(6.18.1)=85^\circ 47\frac{1}{2}'$.

5. AUGELITE FROM ORURO AND TATASI.

Monoclinic crystals of this basic aluminium phosphate ($\text{AlPO}_4 \cdot \text{Al}(\text{OH})_3$), first found in Sweden, have been recently described¹ from two localities in Bolivia, namely from Machacamarca and Tatasi, both in the department Potosi. The present description records the mineral from still another Bolivian locality.

The single specimen (no. 84687) from Oruro on which crystals of augelite have been found has the whole of the free surface, measuring about 28×23 cm., covered with crystals of augelite, mispickel, quartz, iron-pyrites, and stannite. There is a little kaolin, and also some minute yellow globules of cervantite (?) encrusting most of the other minerals. It was not possible to determine with certainty the order of formation of these minerals; the quartz, however, clearly belongs to two generations, there being small crystals on the matrix, and very much smaller crystals encrusting most of the other minerals. The matrix of the specimen consists of massive quartz, iron-pyrites, and tetrahedrite. Cavities at the back of the specimen contain crystals of chalcostibite, andorite, and stannite.

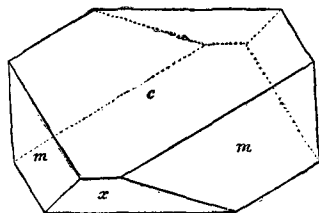


Fig. 3.—Augelite from Oruro, Bolivia.

¹ Min. Mag., 1895, vol. xi, p. 16; 1898, vol. xii, p. 1.

In themselves the crystals of augelite do not differ from those previously described, but the associated minerals are not the same. The well-developed crystals are 2–4 mm. across and are present in large numbers, so that this is by far the best specimen of augelite that has yet been found. The crystals are colourless and transparent, but usually appear to be yellow and opaque, owing to the surface incrustation of cervantite (?). In habit they are tabular parallel to the basal plane $c\{001\}$; the forms $m\{110\}$ and $\omega\{\bar{1}01\}$ are also largely developed (fig. 3). Five crystals were measured on the goniometer, but the only other forms observed were $n\{112\}$ and $o\{\bar{1}12\}$, which are rarely present as narrow faces.

Subsequent to the publication in this magazine of the two previous descriptions of crystallized augelite from Bolivia, other specimens from Tatasi have been sent to the Museum by Mr. Roberts. On one of these specimens (Brit. Mus. no. 86723) the crystals of augelite differ from those hitherto described in having a long-prismatic development. A prismatic habit of augelite has already been mentioned, but in the crystals now referred to it is still more pronounced, and might almost be described as acicular. The prism-faces $m\{110\}$ are irregular, owing to parallel growths, and there are no distinct terminal faces. These crystals are colourless and transparent. They occur, together with pale yellow crystals (*mare*) of chalybite and small octahedra of iron-pyrites, in the cavities of a white volcanic rock (altered dacite), which is sprinkled through with iron-pyrites. Coating the other minerals in the cavities is a white, minutely crystalline mineral with a botryoidal surface; it has a specific gravity of 2.84 and was determined to be *pyrophyllite*.

6. NEW CRYSTAL-FORMS ON VIVIANITE.

The two specimens here described were presented to the British Museum by Mr. M. Roberts; one is from Tatasi and the other from Tasna. The crystals on both have the form of a rectangular prism bounded by $b\{010\}$ and $a\{100\}$, and somewhat flattened parallel to $b\{011\}$: the predominating terminal planes belong to the form $v\{\bar{1}11\}$, and are deeply striated parallel to their intersections with $b\{010\}$. The other faces are bright and smooth, but sometimes, owing to the softness of the crystals, they have been bent by crushing. The colour of the crystals is indigo-blue by reflected light, and sea-green by transmitted light. In each case the associated minerals are chalybite and iron-pyrites, together with some other minerals on one of the specimens.

On the specimen (no. 86726) from Tatasi, two or three vivianite crystals, 1.5 cm. in length, rest on a matrix of massive chalybite, which has a botryoidal surface and is sprinkled throughout with minute crystals of iron-pyrites. The forms¹ determined on one crystal were b {010}, a {100}, y {310}, m {110}, h {250}, z {112}, w {101}, v {111} and s {131}. The new form h {250} is present on three edges as narrow, vertically-striated faces, which gave $ah = 61\frac{3}{4}^\circ$ (calculated $61^\circ 9'$).

The specimen (no. 1905, 101) from Tasma (Eugenia vein, Gabriela gallery) consists of a matrix of brecciated tourmaline-rock cemented with chalybite, which shows large cleavage-surfaces. Associated minerals are needles of white tourmaline, bright cubo-octahedra (with small e {210}) of iron-pyrites, small crystals of chalybite in acute rhombohedra with or without prism-faces a {101}, and a few small crystals of quartz and apatite (see below, p. 338). The largest crystal of vivianite measures 2 cm. in length and 1 cm. across.

The forms determined on one crystal are b {010}, a {100}, y {310}, m {110}, w {101} and v {111}. Between m and b there are narrow planes which are striated vertically and somewhat curved: measurements to a gave in one case 66° , and in another 71° , corresponding with {130} and {140} respectively (calculated $(100):(130) = 65^\circ 20'$, $(100):(140) = 71^\circ 0'$).

On another crystal the forms are b {010}, a {100}, m {110}, n {101}, x {111}, z {112}, w {101}, v {111}, s {131}, r {112}. There are also the same narrow, rounded planes between m and b , giving in this case a band of reflected images at 60° - 67° from a . In the striated zone [bwv] there are two minute planes at 12° from w , corresponding to the position of (838) (calculated $(101):(838) = 12^\circ 7'$).

7. TETRAHEDRITE FROM PULACAYO MINE, HUANCHACA.

Crystallized specimens of fahlerz from this locality are well known in mineral collections. Two distinct types of crystals may be distinguished.

In the more common type, the crystals are steel-grey in colour and have a bright metallic-lustre; the habit is tetrahedral; and the associated minerals are drusy quartz, crystals of copper-pyrites, and massive iron-pyrites. The predominating form is the triakistetrahedron n {211};

¹ The forms and angles are as given by Dana, 'System of Mineralogy,' 6th edit., 1892. Dana erroneously gives s {311} for s {131}.

small faces of the rhombic dodecahedron, $d\{110\}$, are also present. The crystals are usually twinned, with interpenetration, about a triad axis; and these twinned crystals are remarkable in not having the full number of faces of the triakistetrahedron developed. In the octant in which the twin-axis emerges they are completely absent, being replaced by a tetrahedron face (the twin-plane) perpendicular to the twin-axis: the elevation in fig. 4 is represented as bounded at its base by the face $1\bar{1}\bar{1}$, perpendicular to the vertical twin-axis. In each of the other three alternate octants only two faces of the triakistetrahedron are developed; the third being absent or only small in size, as represented at 211 in fig. 6 (this face being here parallel to the twin-axis). Usually, also, one

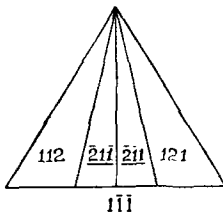


Fig. 4.

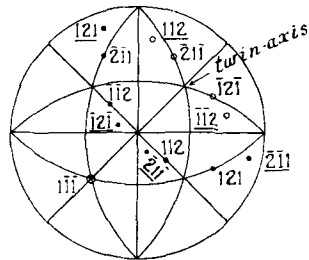


Fig. 7.

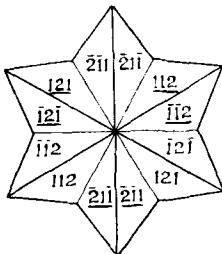


Fig. 5.

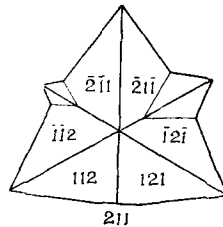


Fig. 6.

FIGS. 4-7.—Tetrahedrite from Pulacayo mine, Bolivia. Plans, elevation, and stereographic projection of twinned triakistetrahedra.

of the interpenetrating crystals predominates in size, and the second crystal is present as disconnected twinned portions projecting as ridges from the main crystal (fig. 6). These projecting ridges may differ in size in the different octants, or may sometimes be altogether absent, their place being then taken by the third triakistetrahedral face of the main crystal (fig. 6).

The second type of tetrahedrite from the Pulacayo mine is much less frequently met with, and in the British Museum is represented by only one specimen (no. 86480), which came from the Hohmann collection. In appearance and habit the crystals are very like the tennantite ('biinnite') from the Binnenthal in Switzerland: they also somewhat resemble crystals of black blende. The colour is iron-black; and the lustre is brilliant and metallic with a velvety appearance. The streak is black. The matrix of the specimen is a decomposed volcanic rock impregnated with iron-pyrites and kaolin. A chemical examination showed the presence of much copper, antimony, and sulphur, some silver and iron, but no arsenic: the crystals are therefore tetrahedrite, and not tennantite. The larger crystals, measuring up to 1 cm. across, are not twinned, and have only the forms $d\{110\}$ and $n\{211\}$, which are approximately equally developed. The smaller crystals are twinned, with interpenetration, about a triad axis. In addition to the forms $d\{110\}$ and $n\{211\}$, these crystals have faces in the zones $[111, 110]$, namely, $\Delta\{774\}$, $p\{221\}$, and $\Sigma\{552\}$. These faces are somewhat uneven and oscillatory in character, and all lie with $n\{211\}$ in the same (positive) octants, the twin-plane ($\bar{1}11$) being in an adjacent (negative) octant. Measurements in this oscillatory zone gave:

	Measured.	Calculated.
$d\Sigma = 110:552$	$15^{\circ} 46'$	$15^{\circ} 48'$
$n\Sigma = 112:552$	$37\frac{3}{4}^{\circ}-38\frac{3}{4}^{\circ}$	$38 56\frac{1}{2}$
$d\Delta = 110:774$	$22\frac{1}{2}^{\circ}-24\frac{1}{2}^{\circ}$	$22 0$
$d\rho = 110:221$	$19^{\circ} 15'$	$19 28\frac{1}{2}$

The form $\Delta\{774\}$ has already been observed on fahlerz from the Pulacayo mine by G. vom Rath¹; and $\Sigma\{552\}$ has been recorded for the Binnenthal tennantite.

8. REGULAR GROUPING OF STANNITE AND TETRAHEDRITE.

A specimen (Brit. Mus. no. 86471), acquired from the collection of the late T. Hohmann, and coming from the Socavon de la Virgen at Oruro, consists of a group of bright crystals of tetrahedrite on a matrix of massive iron-pyrites. The tetrahedrite crystals are tetrahedral in habit and have the forms $n\{211\}$, $o\{111\}$, and $d\{110\}$, the first predominating, as shown in the accompanying figure: the crystals measure 1.5 cm. along the tetrahedral edge. On the free surface of the specimen are crystals (*oae*) of iron-pyrites, and encrusting all the other minerals are small crystals of quartz.

¹ Sitzungsber. niederrhein. Ges., Bonn, 1886, Jahrg. xliii, p. 190.

The stannite crystals are plentifully scattered over the tetrahedrite, in the surface of which they are partly embedded; they are quite small

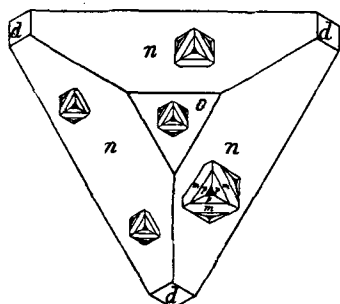


Fig. 8.—Composite pseudo-cubic crystals of stannite in parallel growth on tetrahedrite from Oruro.

($\frac{1}{4}$ – $\frac{1}{2}$ mm. across), and of the same appearance and pseudo-cubic habit as the crystals of stannite previously described from Oruro¹. The stannite is iron-black with a sub-adamantine lustre, while the tetrahedrite is steel-grey with metallic lustre.

The orientation of the pseudo-cubic crystals is parallel to that of the cubic crystals. The three sphenoidal planes, p (111), which in a composite crystal of stannite form a face of the pseudo-tetrahedron, reflect light with a tetrahedron face of the tetrahedrite; and the prism faces, m (110), of the former are parallel (or very nearly parallel) to the rhombic-dodecahedral faces of the latter.

9. AXIAL RATIOS AND ANALYSIS OF VALENTINITE.

Crystals of valentinite are present on four specimens from Tatasi (from the Tusti and Aranzasu veins) presented to the British Museum by Mr. M. Roberts in 1897 and 1899. The crystals are usually flattened parallel to b {010}, and are arranged in fan-shaped groups with the vertical (c) axes of the different crystals coincident. The largest group of crystals measures 1 cm. across. On one specimen, however, the crystals are not grouped together, but are scattered singly over the surface of the matrix, and they are not tabular in habit. The crystals are associated² with octahedra of iron-pyrites on a matrix of a compact, fibrous sulphantimonite of lead with massive iron-pyrites.

The optical characters of the crystals conform with orthorhombic symmetry. The extinction is straight on b (010), m (110), and a (100). The acute, negative bisectrix is perpendicular to a (100); and for red (Li) and yellow (Na) light the plane of the optic axes is parallel to c (001), whilst

¹ Min. Mag., 1901, vol. xiii, p. 54.

² On one specimen there are small crystals of chalybite, pyrrargyrite, and pyrostitpnite. The *pyrostitpnite* has the form of thin blades, which, between crossed nicols, extinguish at 11° to their long edges. Goniometric measurements led to no definite results. On other specimens from Tatasi, blades of pyrostitpnite are associated with crystals of tetrahedrite.

for green (Tl) light it is parallel to $b(010)$; the axial angles are small. The refractive index was determined by Dr. G. F. Herbert Smith through prisms bounded by mm and by bm ; the mean of several determinations with sodium light was 2.34. The dispersion is high, and a prism gives a long spectrum with white light.

Owing to the approximate parallel grouping of the crystals, the faces are much intergrown and are very uneven; and, owing to the softness and perfect cleavages of the crystals, they become distorted at the slightest touch. Further, the vicinal character of the faces in the brachydome zone presents difficulties in the measurement of the crystals. On many of the crystals, however, there are small, smooth, and bright faces of a pyramid, which in being developed on the free corners are less liable to distortion than the other faces.

By carefully detaching crystals, still attached to a fragment of the matrix, from a cavity of one of the specimens, the crystals were measured without being touched, and thus without danger of distortion. In this way some excellent readings were obtained from the pyramid-faces. These faces gave single, sharp images, which could often be observed with the eye-piece of the highest magnification of the Fuess no. 2 goniometer. The means of several readings on the three best crystals are:—

$$oo' = 32^{\circ} 31\frac{3}{4}' \text{ (limits } 32^{\circ} 29\frac{1}{2}' - 32^{\circ} 34').$$

$$om = 40 \quad 9 \quad (\text{ ,, } \quad 40 \quad 5 \quad - \quad 40 \quad 11\frac{1}{2}).$$

This pyramid is new for valentinite, and referred to the axes of Groth and Laspeyres has the indices {554}. Taking it, however, to be the unit pyramid {111}, the angles given above correspond with the axial ratios:—

$$a : b : c = 0.3938 : 1 : 0.4344.$$

Eleven crystals were measured on the goniometer, and the following forms determined:—

- a {100}, a narrow face.
 - b {010}, large, giving scattered images.
 - c {001}, a narrow face; rarely present.
 - m {110}, often curved, owing to the fan-shaped grouping of the crystals and to the fibrous m cleavage.
 - o {111}, small, smooth, and bright faces.
 - i {011}, narrow
 - e {072},
 - r {031}, narrow
 - s {041},
- } These are vicinal faces lying near the positions given by the indices.

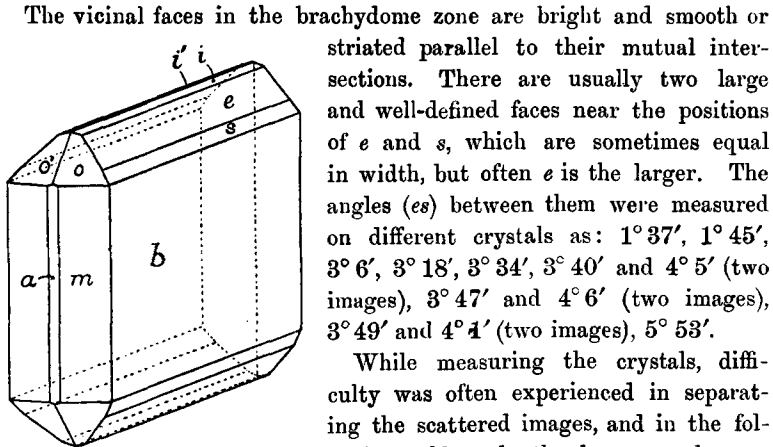


Fig. 9. — Valentinite from Tatasi, Bolivia. (The planes at the further, attached end of the crystal represent the prismatic cleavage.)

The vicinal faces in the brachydome zone are bright and smooth or striated parallel to their mutual intersections. There are usually two large and well-defined faces near the positions of e and s , which are sometimes equal in width, but often e is the larger. The angles (es) between them were measured on different crystals as: $1^{\circ} 37'$, $1^{\circ} 45'$, $3^{\circ} 6'$, $3^{\circ} 18'$, $3^{\circ} 34'$, $3^{\circ} 40'$ and $4^{\circ} 5'$ (two images), $3^{\circ} 47'$ and $4^{\circ} 6'$ (two images), $3^{\circ} 49'$ and $4^{\circ} 1'$ (two images), $5^{\circ} 53'$.

While measuring the crystals, difficulty was often experienced in separating the scattered images, and in the following table only the better angles are given. The calculated angles are deduced from the axial ratios given above.

	Calculated.	Measured.	Limits.	No.
$ii' = (011):(0\bar{1}1)$	$46^{\circ} 57\frac{1}{2}'$	$46^{\circ} 58'$	$46^{\circ} 47' - 47^{\circ} 2'$	3
$ee' = (072):(0\bar{7}2)$	113 20	112 56	112 39 - 113 20	4
$eb = (072):(010)$	33 20	33 4	32 21 - 34 23	9
$rb = (031):(010)$	37 30	37 3	36 19, 37 48	2
$ss' = (041):(0\bar{1}1)$	120 9	119 42		1
$sb = (041):(010)$	29 $55\frac{1}{2}$	29 43	28 44 - 30 39	9
$oi = (111):(011)$	45 20	45 $10\frac{1}{2}$	45 $3\frac{1}{2}$ - 45 15	4
$oe = (111):(072)$	53 $59\frac{1}{2}$	53 43	53 37 - 53 46	6
$os = (111):(041)$	55 $38\frac{1}{2}$	55 23	55 12 - 55 34	3
$mm' = (110):(1\bar{1}0)$	42 59	42 20	$40\frac{1}{2}^{\circ} - 43\frac{1}{2}^{\circ}$	6

The measured angles for the vicinal faces thus vary considerably from the calculated values, but far wider variations than those recorded above were observed. The measurements of the prism-angle also varied between wide limits¹.

The axial ratios and complex indices of valentinite have been critically studied by P. von Groth (1869 and 1874), H. Laspeyres (1884), and A. Brezina (1886); but since previous calculations are based on measurements made in the brachydome- and prism-zones, the problem

¹ Values previously given for the prism (cleavage) angle are: $42^{\circ} 17'$ (W. Phillips, 1823), $43^{\circ} 2'$ (F. Mohs, 1824), $42^{\circ} 18'$ (P. von Groth, 1869), $41^{\circ} 50'$ (P. von Groth, 1874), $42^{\circ} 41'$ (H. Laspeyres, 1884).

has been complicated by deducing axial ratios after high indices have been assigned to the faces, which are really only vicinal in character. The parametral plane selected above, and now, for the first time, observed as an actual crystal-face, was chosen by Brezina¹ in the more likely of his two interpretations of the crystals; and, from Laspeyres's measurements, he deduced the axial ratios $a:b:c = 0.3915:1:0.4205$, corresponding with those given above.

These axial ratios have, however, the disadvantage of failing to indicate the isomorphism of valentinite with the monoclinic claudetite (As_2O_3). But since no analysis² has been made of the former mineral, there is no direct evidence that the formula is Sb_2O_3 . It was, therefore, thought advisable to analyse the Bolivian crystals. For this purpose 0.5498 gram of pure crystallized material was collected by Dr. G. F. Herbert Smith and analysed by Dr. G. T. Prior, with the following results, which agree with the accepted formula Sb_2O_3 :—

		Atomic ratios.
Sb	82.79	0.693 2
O (by difference) ³	17.21	1.084 3
As	trace ⁴	
<hr style="width: 50%; margin-left: auto; margin-right: 0;"/>		
100.00		
Specific gravity ⁵	5.76	

Most of the observations recorded above were made in 1897, and although not altogether satisfactory, they may be of some value beyond recording a new locality for the mineral. The crystals were also measured by Dr. G. F. Herbert Smith, but with no further results, and he also found them to be unsuitable for accurate determinations of the optical constants.

¹ Ann. k.k. naturhist. Hofmus. Wien, 1886, vol. i, p. 145.

² An analysis of acicular crystals of 'white antimony' from Pereta in Tuscany gave E. Bechi (Amer. Journ. Sci., 1852, ser. 2, vol. xiv, p. 60) Sb, 78.83; O, 19.47; Fe, 1.25; gangue, 0.75 = 100.30. This suggests the formula Sb_2O_3 , and is quoted by Dana ('System of Mineralogy,' 5th edit., 1868, p. 187) under cervantite.

³ An attempt to determine the oxygen directly, by heating the mineral in a current of hydrogen and weighing the water so formed, was unsuccessful, owing to the ready fusibility of the reduced metal.

⁴ Detected by the Babo-Fresenius test.

⁵ The value, 5.566, usually quoted for the specific gravity of valentinite, is due to W. Haidinger (Edinburgh Journ. Sci., 1825, vol. ii, p. 73; and quoted earlier in F. Mohs's 'Grund-Riss d. Mineralogie,' 1824).

10. CASSITERITE.

Specimens of cassiterite collected by Sir Martin Conway from the mountain of Huaina Potosi, near La Paz, are compact to fine-grained in texture, and light to dark brown in colour; they are often iron-stained. Except for the heaviness (specific gravity) of the specimens there would be nothing to suggest on a casual examination that the material is cassiterite. Cavities are lined with minute, very indistinct crystals of cassiterite, which are light to dark brown, and translucent to opaque. Quartz, iron-pyrites, and sometimes bismuthinite (Bi_2S_3) are present in small amounts, mixed with the massive cassiterite. In one specimen the grains of cassiterite are embedded in a dirty green chloritic substance. A thin section of this specimen shows, under the microscope, an iron-stained aggregate of cassiterite, chlorite, and quartz: the cassiterite grains are frequently twinned.

The most coarsely crystallized specimen (Brit. Mus. no. 84694 A), from the Chacaltaya mine, on Huaina Potosi, shows in the cavities dark crystals

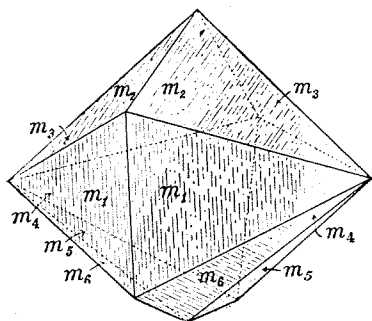


Fig. 10.—Cassiterite from Huaina Potosi, Bolivia.

Six crystals twinned together, producing a pseudo-hexagonal bipyramid.

present is the deeply striated prism $m \{110\}$, with very narrow planes of $a \{100\}$ on a few of the edges. In fig. 10 the six individuals are marked $m_1 \dots m_6$; of these, m_1 is placed in the normal position with the prism-edge and the striations vertical. The second and sixth crystals are twinned on $(\bar{1}01)$ and $(\bar{1}0\bar{1})$ respectively of the first crystal; the fifth and sixth are in twin position with respect to the fourth and first respectively, but not with respect to each other. This type of repeated twinning with the twin-axes all in the same plane is frequent in rutile, but rare in cassiterite¹.

¹ W. Phillips, *Trans. Geol. Soc. London*, 1814, vol. ii, p. 373, plate 25, figs. 208–15. W. Haidinger, *Edinburgh Journ. Sci.*, 1825, vol. iii, p. 61, plate 3, fig. 7.

Sir Martin Conway's collection also includes specimens from Oruro of much the same character: they are heavy, pale brown, somewhat porous masses, with minute and indistinct crystals of cassiterite lining the cavities. In the cavities of one specimen are pentagonal dodecahedra $e\{210\}$ of iron-pyrites, and in another the cavities are lined with small quartz crystals. Massive iron-pyrites and a black mineral with metallic lustre occur in small quantities intermixed with the massive cassiterite. A thin section of a specimen from the San José mine shows, under the microscope, a porous aggregate of small, interlocking, pale yellow crystals of cassiterite. The index of refraction and the double refraction are high. Twinning is frequent, and sometimes often repeated; the line of junction between the individuals of a twin is always sharp and straight.

Compactness is a characteristic feature of Bolivian tin-ores. Crystals of cassiterite, other than those of minute size, are only exceptionally met with: in the British Museum collection there are only four isolated crystals of any appreciable size. They are simple (i. e. not twinned) crystals of prismatic habit. One of them (Brit. Mus. no. 86822) measures $20 \times 5 \times 5$ mm., and was sent by Mr. M. Roberts from Tasna; it has the forms $m\{110\}$ and $s\{111\}$. Two crystals (Brit. Mus. no. 87070) from Tres Cruces (= Quimza Cruz) in the province Inquisivi, department La Paz, were presented by Mr. John B. Minchin in 1904. The larger of these measures $21 \times 11 \times 11$ mm., and has the forms $m\{110\}$, $e\{101\}$, $s\{111\}$, $z\{321\}$, and $t\{313\}$; the prism faces are roughly striated and uneven, being replaced by oscillatory vicinal faces $\{970\}$, $\rho\{750\}$, &c. The rather smaller crystal, on which the same forms are present, is translucent and shows zonal bands of colour (brown, yellow, and almost colourless) parallel to the z planes: it is distinctly pleochroic, the absorption being greater for vibrations parallel to the vertical (c) axis, although the tone of the colours remains the same. Both Mr. Minchin and Dr. Richard Pearce have informed me that good, crystallized specimens of cassiterite, with larger crystals than those here described, are by no means uncommon at Tres Cruces.

11. TOURMALINE AND TOURMALINE-HORNFELS FROM TASNA.

Tourmaline of quite an unusual habit and appearance was unexpectedly found on several specimens sent by Mr. M. Roberts in 1905 from the tin and bismuth mines at Tasna, province of Nor-Chichas, department of Potosi. The mineral has the form of very fine, colourless or pale greyish-green needles, but owing to differences in the state of aggrega-

tion it varies considerably in appearance. The associated minerals are cassiterite, wolframite, mispickel, iron-pyrites, marcasite, quartz, vivianite, chalybite, apatite, and native sulphur, but these are not all present together on the same hand-specimen.

The needles, taken from different specimens, have a maximum length of 1 to 2 mm. and a thickness of 0.01 to 0.05 mm. Under the microscope, in ordinary light, they are seen to be very faintly tinged with green: sometimes the needles are slightly lighter in colour at their flat pyramidal terminations. The pleochroism is feeble, yet distinct: for vibrations parallel to the length of the needles the transmitted light is colourless, and for vibrations perpendicular thereto it is faint yellowish-green or sometimes bluish-green. The needles extinguish parallel to their length, and are optically negative. The specific gravity is 3.0. Chemical tests proved the presence of boron.

On one specimen the tourmaline forms the matrix of crystals of wolframite and mispickel¹, and has, at first sight, the appearance of a pale greenish-grey vesicular lava. This consists of a more or less compact, matted aggregate of the fine tourmaline needles, which are best seen in the round cavities, where they are more loosely aggregated. On another specimen the tourmaline needles are shorter and smaller and form a more or less compact, yellowish or dark-grey rock, somewhat resembling a sandy shale in appearance: this tourmaline-rock has been brecciated and the fragments cemented together with chalybite, on which is a later growth of tourmaline needles. On a third specimen, a few rather larger, colourless needles are confusedly grouped with quartz crystals and brilliant tin-white crystals of mispickel (forms *m* and *e*) in a cavity in massive mispickel and iron-pyrites. On a fourth, the tourmaline has the form of very fine, colourless or white, silky hairs growing out from a matrix of tourmaline-hornfels impregnated with small, indistinct crystals of cassiterite. On a fifth specimen, the bluish-greenish needles form small divergent tufts, with a velvety appearance, on the mamillated surface of brown, compact cassiterite with massive iron-pyrites. Only

¹ The *wolframite* crystals have a brilliant lustre and are tabular parallel to $t \{102\}$; the following forms were determined by the goniometrical measurement of one crystal:— $a \{100\}$, $b \{010\}$, $c \{001\}$, $t \{102\}$, $m \{110\}$, $l \{210\}$, $f \{011\}$, $\omega \{111\}$, $g \{121\}$.

The *mispickel* (arsenopyrite) crystals are bright with a purplish tarnish: in habit they are exactly like fig. 2 in Dana's 'System of Mineralogy' (6th edit., 1892, p. 98), though in addition to the forms $e \{101\}$ and $m \{110\}$, which are equally developed, there are very narrow faces of $c \{001\}$.

on this last specimen is there any attempt at radial grouping of the needles; more usually they are confusedly aggregated or matted.

This colourless, acicular tourmaline is not unlike the achroite or white schorl sometimes met with in the Cornish tin mines. Such material has been described by Mr. J. H. Collins¹ from St. Austell, and in the British Museum collection there are specimens from St. Austell and St. Just.

The matrix of several of the specimens sent by Mr. Roberts from Tasna consists of a very compact, hard rock resembling in appearance a hornstone or a very fine-grained quartzite. This rock I have determined to be a *tourmaline-hornfels*. It occurs in the mineral-veins, and, on different hand-specimens, is associated with cassiterite, wolframite, native bismuth, bismuthinite (Bi_2S_3), iron-pyrites, mispickel, quartz, and tourmaline. It also appears to be of common occurrence amongst the rocks of the Cerro de Tasna, for in a collection of eighteen representative rock-specimens² sent by Mr. Roberts half of them are tourmaline-hornfels. One specimen, from the summit of the mountain (5,213 metres above sea-level), is a brecciated tourmaline-hornfels, with the fragments set in a matrix of silvery white scales of *pyrophyllite*³.

These rocks are usually pale buff- or cream-coloured or greyish; sometimes they show darker bands or are spotted like a spilosite. They have a specific gravity of 2.8 and a hardness of about 7. Thin sections under the microscope show a microcrystalline aggregate of two minerals, one with the birefringence of quartz, and the other with a higher birefringence. The latter is very pale yellowish-green in colour and is not noticeably pleochroic: it predominates in the darker coloured bands and spots of the rock. The suggestion that this mineral might be tourmaline, and the rock a tourmaline-quartz-rock, was given by noticing in a small cavity of one of the specimens some small colourless needles of the same character as those described above, which were identified as tourmaline. A mixture of quartz and tourmaline in about equal proportions would have a specific gravity of 2.8. The rocks were tested for boron, and in each case gave a good flame-colour reaction.

Mr. M. Roberts, who has been actively engaged in mining in Bolivia since 1893 and at Tasna since 1903, writes (November, 1906) to me respecting the rocks of the Cerro de Tasna—'Within 400 metres from the summit there is certainly more tourmaline-hornfels than any other rock. Round the base are the shales, and in these I know of three

¹ Min. Mag., 1876, vol. i, p. 55.

² These include altered dacite, clay-slate, quartz-grit, and quartzite.

³ Another Bolivian occurrence of pyrophyllite is noted above (p. 324).

dacite-dykes, which are 5 to 15 metres in width: there is no boss of dacite. . . . Personally I have never seen granite¹ in Bolivia and I feel sure that there is none anywhere in the neighbourhood of Tasna.' In a previous letter he remarked that the hard, compact 'quartzites' (i. e. tourmaline-hornfels) present a difficulty in the exploitation of the tin-veins.

There thus seems to be an abundance of tourmaline associated with the tin and bismuth ores of Tasna, and the reason why it has been previously overlooked can only be ascribed to the peculiar form which the mineral takes. The frequent occurrence of a hard, compact hornfels was mentioned by the late Professor A. W. Stelzner²; and he considered it to be a silicified product of the clay-slates, formed either in connexion with the mineral-veins or by metamorphic action of the dacite-dykes.

The supposed absence of tourmaline in the tin-veins of Bolivia has been especially emphasized by Stelzner³, and hitherto only a few isolated occurrences have been recorded. In his earlier Bolivian paper⁴, Stelzner mentions in a footnote the occurrence of tourmaline in the tin-veins of Chorolque; but in his later, posthumous paper⁵ it is only mentioned by the editor in an appendix, the authority being Stelzner's labels with two specimens in the Freiberg collection.

D. Forbes⁶ mentions it as occurring in the Baldomero mine on Mount Illampu, near Sorato, together with gold, bismuth, tetradyomite, apatite, &c. Prof. T. G. Bonney⁷ also notes the presence of tourmaline, in radiating groups of black acicular crystals with quartz and felspar, amongst the rock-specimens (granite, &c.) collected by Sir Martin Conway on Mount Sorata (= Illampu).

Dr. R. Pöhlmann⁸ in his description of the Hohmann collection mentions eight specimens of tourmaline from Chilian and Bolivian ore-deposits. Dr. G. F. Kunz⁹, in his annual report on precious stones for

¹ Specimens of granite were collected by Sir Martin Conway high up on Mt. Sorata (see 'Bolivian Andes', p. 373).

² A. W. Stelzner. 'Die Silber-Zinnerz-lagerstätten Bolivias. Ein Beitrag zur Naturgeschichte des Zinnerzes.' Zeits. Deutsch. geol. Ges., 1897, vol. xlix, pp. 51-142 (see pp. 135-6). ³ Loc. cit., p. 116.

⁴ Zeits. Deutsch. geol. Ges., 1892, vol. xlv, p. 532 (footnote).

⁵ Ibid., 1897, vol. xlix, p. 137.

⁶ Phil. Mag., 1865, ser. 4, vol. xxix, p. 2.

⁷ Sir M. Conway, 'The Bolivian Andes,' 1901, p. 372.

⁸ Verh. Deutsch. wiss. Ver. Santiago de Chile, 1899, vol. iv, p. 83. Most of these specimens are probably from Chilian copper-lodes.

⁹ Mineral Resources of the United States, for 1903, 1904, p. 966 (p. 60 of reprint).

1903, quotes, on the authority of Dr. G. F. Bandelier, 'Tourmaline.—The common black variety accompanying cassiterite occurs near La Paz.' Lastly, Dr. Richard Pearce¹ mentions the occurrence of delicate, greenish needles of tourmaline with tin-ore in the Tres Cruces district; and he has informed me that it is there rather abundant.

12. FLUORITE.

In a cavity of the more coarsely crystallized specimen (Brit. Mus. no. 84694 A) of cassiterite from the Chacaltaya mine, Huaina Potosi, mentioned above, there is a group, about 1 cm. across, of corroded crystals of white fluorite, associated with quartz and limonite. The crystals appear to be octahedra, and were found to possess the physical, optical, and chemical characters of fluorite. The refractive index was determined, through a prism bounded by the cleavages, to be about 1.44.

This occurrence is of interest, since fluorite is of extremely rare occurrence in Bolivia. Both Arzruni² and Stelzner³ have remarked on its absence from the tin-stone veins of this region. Curiously enough, however, worked beads of pale-yellow and rose-red fluorite have been found by A. Stübel⁴ in the ancient ruins of Tiahuanaco on Lake Titicaca. It has been suggested that this material was brought by the Incas from some locality now in Peru.

D. Forbes⁵ in 1861 gives fluor-spar in his list of minerals occurring in the mineral-veins of Bolivia, but he gives no precise locality or other details. I. Domeyko⁶ in 1879 recorded its occurrence with the copper ores (not tin) in the Cretaceous strata at Corocoro near La Paz, and recently⁷, transparent, green fluorite from this locality has been mistaken for emerald.

C. S. Pasley⁸ states that fluorite is found with iron-pyrites and tin-

¹ Trans. R. Geol. Soc. Cornwall, 1906, vol. xiii, p. 105. It is here stated that Mr. D. A. MacAlister has detected tourmaline in a specimen of Bolivian tin-ore.

² Zeits. Kryst. Min., 1884, vol. ix, p. 75.

³ Zeits. Deutsch. geol. Ges., 1897, vol. xlix, p. 116.

⁴ Zeits. Kryst. Min., 1880, vol. iv, p. 370; 1881, vol. v, p. 580.

⁵ Quart. Journ. Geol. Soc., 1861, vol. xvii, p. 60.

⁶ I. Domeyko, 'Mineralojia,' 3rd edit., Santiago de Chile, 1879, p. 717.

⁷ G. F. Kunz, Mineral Resources of the United States, for 1903, 1904, p. 963 (p. 62 of the reprint of Kunz's annual report on precious stones, for 1903). W. J. Humphreys (Astrophysical Journ., Chicago, 1904, vol. xx, p. 269) has found yttrium and ytterbium to be present in this fluorite.

⁸ C. S. Pasley, 'The tin mines of Bolivia.' Trans. Inst. Mining and Metallurgy, London, 1899, vol. vii, pp. 77-90. Fluorite is mentioned on p. 83.

stone at Colquiri in the province of Inquisivi, fifty miles north of Oruro. A series of Bolivian tin-ores and mineral specimens was presented by Mr. Pasley in 1898 to the Museum of Practical Geology, London, and amongst them is a specimen of green and purple fluorite from Colquiri, the determination of which as fluorite Dr. W. Pollard has been kind enough to confirm for me. Another mention of Bolivian fluorite is to be found in the Annual Report¹ for 1900-1 of the Museum Senckenbergianum at Frankfurt-am-Main: it is contained in a list of Chilian and Bolivian minerals collected by A. Gmebling, and reads 'Fluorit vom Gang Lipez (Bolivia)'.

13. APATITE.

On the specimen of vivianite from Tasna (Eugenia vein, Gabriela gallery), described above (p. 325), there are a few minute crystals of apatite. One rests directly on a crystal of vivianite, and another, with needles of white tourmaline, is attached to a small crystal of chalybite, which rests on the same crystal of vivianite. The apatite crystals are colourless and transparent, and are beautifully perfect. They are prismatic in habit, and have a length of about 1 mm. The predominating forms are the hexagonal prism, m {1010}, and the basal pinacoid, c {0001}. Other forms, present as small, but distinct faces, are the prism a {1120} and the pyramids x {1011}, y {2021}, and s {1121}. The measured angles agree closely with the values given by Dana; for example, $my = 30^\circ 30'$ (calculated, $30^\circ 31'$). A rough determination of the refractive index, by refraction through the natural prism, gave 1.64. The amount of material was too small for a determination of the specific gravity and for any chemical tests to be made. The refractive index is, however, sufficient to prove that the crystals are apatite, and not pyromorphite or mimetite.

Mention may also be made here of a fine crystal of apatite 'from Bolivia', which was presented to the British Museum in 1903 by Miss Louie Hicks, and was from the collection of her late father, Mr. George Hicks. The meteorites and mineral specimens presented to the British Museum by Mr. Hicks in 1879 were all from the Desert of Atacama, at that time in Bolivian territory, but now in Chili, and it is possible that the apatite crystal may have come from the same region; at any rate, there is nothing to connect the specimen in question with the tin deposits of the Bolivian plateau to the east of the Andes.

¹ Ber. Senckenb. Naturf. Ges., 1901, I Theil, p. 53.

This specimen (Brit. Mus. no. 86618) is an isolated, stout-prismatic crystal, broken at one end, and without any attached matrix. It measures $4\frac{1}{2}$ cm. in length by 3 cm. in diameter. It is translucent and of a fine oil-green colour; but on the prism-planes there is a thin shell or skin of white, opaque material (apatite). The forms $c\{0001\}$, $x\{10\bar{1}1\}$, $a\{11\bar{2}0\}$, and $m\{10\bar{1}0\}$ are all prominently developed; the prism-faces a are wider than m , so that the pyramid-faces x are set on the corners of the former prism.

Apatite, like fluorite, tourmaline, and topaz, has been considered to be absent from the Bolivian tin-veins; and, indeed, these minerals have been only occasionally recorded from this region. This may, perhaps, be accounted for by their inconspicuousness and unusual modes of occurrence. A. W. Stelzner in his earlier Bolivian paper mentions¹ the occurrence of apatite, as a rarity, in the tin-veins of Tasna; but in his later, posthumous paper it is only given² by the editor in an appendix, the authority being Stelzner's label 'Apatit auf Zinnerz von Tasna' belonging to a specimen in the Freiberg collection. Other statements of the occurrence of apatite in Bolivia are the following. According to D. Forbes³ it is found in the San Baldomero mine on Mount Illampu, near Sorata, together with gold, bismuth, tetradymite, tourmaline, &c. I. Domeyko⁴ mentions large crystals of fluor-apatite from the silver mines at Aullagas, near Colquechaca.

In addition to these occurrences, certain pseudomorphous impressions in compact cassiterite have been suggested to be after apatite. Domeyko⁵ mentions a specimen of tin-ore from Bolivia (Oruro or Guanuni) with impressions of hexagonal prisms terminated by obtuse rhombohedra. And Stelzner⁶ mentions tin-ore from Tasna with impressions of hexagonal prisms with basal planes.

14. CUPRIFEROUS MIARGYRITE FROM TATASI.

A specimen (Brit. Mus. no. 84307), consisting mainly of massive miargyrite with some massive iron-pyrites, was presented to the Museum

¹ Zeits. Deutsch. geol. Ges., 1892, vol. xlv, p. 532 (footnote).

² Ibid., 1897, vol. xlix, p. 137.

³ Phil. Mag., 1865, ser. 4, vol. xxix, p. 2.

⁴ I. Domeyko, 'Mineralojia,' 3rd edit., 1879, p. 498. The statement was first made in 1867 in the 2nd appendix to the 2nd edition (Anales de la Universidad de Chile, 1867, vol. xxix, p. 76).

⁵ Bull. Soc. Min. France, 1882, vol. v, p. 299. The rhombohedral terminations do not suggest apatite.

⁶ Loc. cit., 1897, pp. 137, 138.

by Mr. M. Roberts in 1897. It is from the Consuelo lode at Tatasi, in the department of Potosi. In cavities there are small spindle-shaped crystals of pale yellow chalybite, some radiating groups of quartz crystals, a few small octahedra of iron-pyrites, and a powdery coating of cervantite (?). Other cavities, in which these minerals are absent, are lined with bright crystal-faces of miargyrite, but only small fragments of crystals could be detached for goniometric measurement, which gave uncertain results.

The massive miargyrite is black and opaque, and has a bright metallic lustre. Thin flakes, when examined under the microscope in bright sunlight, transmit a deep crimson colour. The streak is dark purple to reddish-brown. The fracture of the mineral is uneven to sub-conchoidal, with traces of cleavage. The specific gravity is 5.20, and the hardness $2\frac{1}{2}$. A qualitative chemical analysis showed the presence of sulphur, antimony, silver, copper, iron, and a trace of arsenic.

These characters point either to miargyrite or to a richly argentiferous tetrahedrite, and to distinguish between these it became necessary to make a quantitative analysis. I obtained the following results, which agree with the miargyrite formula, AgSbS_2 , with part of the silver replaced by copper ($\text{Ag} : \text{Cu} = 8 : 1$). Lead is not present in fragments of pure miargyrite giving a purplish streak, but in an intermixed mineral of similar appearance with a black streak.

			Atomic ratios.		Calculated for $8 \text{AgSbS}_2 + \text{CuSbS}_2$.	
S	...	21.9	...	0.69	...	22.3
Sb	...	40.5	...	0.34	...	41.9
Ag	...	33.9	...	0.32	...	33.4
Cu	...	2.6 ¹	...	0.04	...	2.4
Fe	...	1.0	...	0.02		
Pb	...	0.6				100.0
As	...	trace				
						<hr/>
						100.5

15. MIARGYRITE FROM AULLAGAS.

Mention has already been incidentally made in this magazine² of the occurrence of crystallized miargyrite at Aullagas, near Colquechaca in

¹ Two determinations gave 2.69 and 2.63 per cent. of copper. No copper mineral was detected on the specimen.

² Min. Mag., 1898, vol. xii, p. 12.

province Chayanta, department Potosi. The specimen, belonging to the Allan-Greg collection, there described consists of massive brongniardite and miargyrite, with some galena, pyrargyrite, and blende, and situated on the miargyrite are small octahedral crystals of argyrodite. The miargyrite is distinguished from the other minerals by its uneven fracture with traces of cleavage and by its dark cherry-red streak. It was examined chemically, and found to contain silver, antimony, and sulphur. In the cavities of the massive material some inconspicuous crystals of miargyrite were found: the following forms¹ were noted on the four fragmentary crystals measured:—

- (i) $b \{010\}$, $t \{111\}$, $s \{211\}$, $d \{311\}$, $\zeta \{215\}$, $\chi \{212\}$, $\sigma \{211\}$, $x \{122\}$. A bright crystal, not much striated; b is very small. The prominent zones are $[dtx\sigma]$ and $[s\sigma\chi\zeta]$.
- (ii) $c \{001\}$, $t \{111\}$, $s \{211\}$, $h \{113\}$, $k \{124\}$, $x \{122\}$. c is large.
- (iii) Like No. 2 with $d \{311\}$, but without k .
- (iv) $a \{100\}$, $c \{001\}$, $t \{111\}$, $s \{211\}$, $d \{311\}$, $g \{313\}$.

Some of the best measured angles are:

	Calculated.	Measured.
$tt' = 111 : \bar{1}\bar{1}\bar{1}$	$54^\circ 55\frac{1}{2}'$	$54^\circ 38'$
$ts = 111 : 211$	$14 17\frac{1}{2}$	$14 21, 14^\circ 10'$
$tc = 111 : 001$	$69 18$	$68 50, 68^\circ 54'$
$s'\sigma = \bar{2}\bar{1}\bar{1} : 211$	$32 2\frac{1}{2}$	$31 53$
$ck = 001 : 124$	$54 36$	$54 12$

Similar crystals of miargyrite are also present on a specimen², labelled Potosi, which was collected by the Castelnau expedition (1843-7); the associated minerals are exactly the same as on the specimen described above, from Aullagas, department Potosi.

Mention may be made here of a large specimen of massive miargyrite, from the silver mines of the Colquechaca Company at Aullagas, a fragment of which is in the British Museum collection (no. 83989). In cavities in the bright, massive miargyrite are a few wires of native silver and some small crystals of pyrargyrite. The matrix is a brecciated, light-coloured rock, in the interstices of which are lenticular crystals of chalybite, crystals of reddish-brown blende and quartz, and some iron-pyrites and galena.

¹ The letters, indices, and calculated angles here given are those of Dana, 'System of Mineralogy,' 6th edit., 1892, p. 116.

² This specimen has been mentioned under argyrodite (Min. Mag., 1898, vol. xii, p. 13).

Although Bolivia has long been famous for its richness in silver, comparatively few species of silver-bearing minerals have been identified. The principal silver-ore is argentiferous tetrahedrite. The present notes add miargyrite and pyrostilpnite (p. 328) to the list¹.

16. JAROSITE FROM CHOCAYA, DEPT. POTOSI.

A small specimen (Brit. Mus. no. 86727) from this locality, presented by Mr. M. Roberts in 1903, has the aspect of ochre-yellow semi-opal, and had been mistaken for compact cassiterite. In cavities, the surface is mamillary and encrusted with very minute, sparkling crystals of a reddish-brown colour. A little granular galena is embedded in the opal-like mass. The crystals are optically uniaxial and negative, and the massive material is finely crystalline and birefringent. The specific gravity is 3.0, and the hardness about 4. A chemical examination made by Dr. G. T. Prior proved the material to be a hydrated sulphate of iron, potassium, and sodium, and therefore to be jarosite.

17. CHALYBITE FROM CHOROLQUE AND TATASI.

Chalybite is of rather frequent occurrence in the mineral-veins of Bolivia, but usually only as small, indistinct crystals: it is invariably associated with iron-pyrites. Fine groups of large, bold crystals are found at the Cerro de Chorolque in province Sud-Chichas, department Potosi. A specimen (Brit. Mus. no. 86468), from the Hohmann collection, shows a number of crystals, measuring $3\frac{1}{2}$ cm. along their rhombohedral edges, grouped together on the flat surface of a dark-coloured, slaty rock: the group of crystals measures 20×10 cm. Between the chalybite and the rock is some black blende with metallic lustre and a little iron-pyrites. The crystals have the form of the rhombohedron $f\{\bar{1}11\} = \{02\bar{2}1\}$, with large flat faces faintly striated parallel to their longer diagonal. The edges are rounded by etching, and the faces are also dulled and roughened from the same cause. A surface coating of clay also detracts from the appearance of the crystals. In the interior, however, they are pale yellow, transparent, and clear. There are no indications of sub-parallel grouping or curvature of the crystals, as is so often the case in chalybite; and the cleavage-surfaces, which truncate the rhombohedral edges, are perfectly bright and smooth.

On another, similar specimen from the same locality, two of the large rhombohedra, $f\{\bar{1}11\}$, are twinned with interpenetration, the twin-plane

¹ In addition to the silver minerals from Aullagas mentioned above, crystals of stephanite have been described (Min. Mag., 1893, vol. xii, p. 6, footnote).

being c (111) and the vertical axes of the two crystals coincident (fig. 11). The other crystals on the specimen are simple. This twin-law, though common in calcite and dolomite, is not mentioned in the textbooks for chalybite. On a third specimen the more deeply etched rhombohedra of chalybite form one side of a vein of bismuthinite (Bi_2S_3).

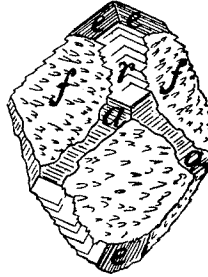
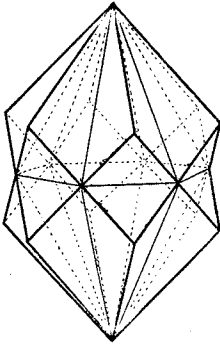


Fig. 11.—Chalybite from Chorolque.

Fig. 12.—Chalybite from Tatasi,
 f {111} twinned on (111).

Large crystals of chalybite are present on a specimen (Brit. Mus. no. 87096), also from the Hohmann collection, from the Tusti vein at Tatasi. The crystals (fig. 12), measuring 3 cm. across, are here associated with bright cubo-octahedra of galena. They have the forms r {100}, e {110}, a {10 $\bar{1}$ }, and f { $\bar{1}$ 11}. The faces r , e and a are striated parallel to the zone-axis [era]; the narrow e and a being deeply striated and uneven, while the larger r is plane. f is represented only by rough, somewhat cavernous areas formed by numerous small projecting faces which reflect light together with r , e , and a . Except on the smoother r faces, these large crystals have quite the appearance of being built up of small lenticular individuals with the forms r , e and a , the last being quite narrow. Several small crystals of this kind are present on the galena and on other parts of the specimen; these are pale yellow and transparent, while the larger crystals appear to be darker in colour.

Another type of chalybite crystals, more commonly met with at Tatasi, is that of small, slender spindles, 1 to 2 mm. in length. These are striated longitudinally, and under the microscope have quite the appearance of pin-points. They probably represent very acute rhombohedra with curved faces. When these crystals are dissolved in acid they leave an abundant residue of microscopic needles, which appear to be quartz.

The best examples of these spindle-shaped crystals of chalybite are to be seen in the cavities of the massive miargyrite from Tatasi (p. 340). They form a strong contrast to the lenticular crystals of chalybite associated with the massive miargyrite from Colquechaca (p. 341).

The small crystals of chalybite associated with vivianite from Tasna (p. 325) have the form of acute rhombohedra, with or without the prism $a \{10\bar{1}\}$: the faces, though plane, are too dull and drusy for their indices to be determined on the reflecting goniometer. The crystals with the augelite from Tatasi (p. 324) are short hexagonal prisms, $m \{2\bar{1}\bar{1}\}$, terminated by $r \{100\}$ and $e \{110\}$.

18. ENARGITE FROM CHOROLQUE.

A specimen (no. 86467) in the British Museum collection is accompanied by a label in T. Hohmann's handwriting—'Enargite: Mina Coronacion, Chorolque'; and the same information appears in Hohmann's MS. catalogue. R. Pöhlmann, in his description of the Hohmann collection¹, mentions enargite from Argentina and from Chorolque in Bolivia in the form of columnar crystals 1 cm. in length.

The specimen shows a number of bright, well-developed crystals of enargite covering a surface of massive iron-pyrites and fahlerz. The only forms present are $c \{001\}$, $a \{100\}$, and $m \{110\}$, all of large size: a and m are vertically striated, and c is striated parallel to its intersection with a . The crystals are tabular parallel to a . Being closely grouped, and with the prism-edges approximately perpendicular to the underlying matrix, the crystals appear to be quite short in the direction of the vertical axis, and the bright basal planes produce a kind of tessellated surface to the specimen. The crystals measure about 1 cm. across the basal planes in their longer direction, and the bright prismatic cleavage surfaces at the edges of the specimen have about the same length.

The specimen is not unlike those from the Sierra Famatina in Argentina, but at the latter locality the crystals of enargite seem to be always associated with small crystals of quartz. I. Domeyko in his 'Mineralogia' makes no mention of enargite from Bolivia, but G. Bodenbender² gives Bolivia without any precise locality.

¹ Verh. Deutsch. wiss. Ver. Santiago de Chile, 1899, vol. iv, p. 80.

² G. Bodenbender, 'Los Minerales . . . en la República Argentina,' Córdoba, 1899, p. 54.