Paratacamite, a new oxychloride of copper.

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ABOUT two years ago there was brought to the British Museum a specimen covered with numerous small cubes—so the crystals appeared to be—of the bluish-green colour suggestive of a mineral containing copper. Judged by their form the crystals might be boleite, but a qualitative analysis by Dr. Prior, while revealing the presence of chlorine and copper, showed no trace of lead. A crystal was then removed from the specimen and measured on a goniometer, and the discovery was at once made that these apparent cubes are in reality rhombohedra with an angle of nearly 88° between adjacent faces. Since no previously known oxychloride of copper crystallizes in this form, these crystals were evidently worthy of further investigation. Inquiry elicited the information that the specimen was one of between seven and eight hundred, mostly mineral, specimens which had been collected in Chili by a mining engineer, of the name A. Anabalón y Uryúa; the manuscript catalogue of the collection is dated September 1899. The collection ultimately came into the hands of Mr. F. H. Butler, of London, and, his attention having been directed to these curious crystals, he brought the specimen to the Museum. As it was desirable to accumulate as much material as possible for a complete examination of the properties of this new mineral, all those specimens in the collection which showed any green crystals were examined. Many turned out to be atacamite; but other specimens were found which displayed crystals of the new mineral, all of which were acquired by the Trustees of the British Museum, with the exception of two, which had previously been purchased by Mr. Arthur Russell, who with ready courtesy, which the author gladly acknowledges, lent them for the purposes of this investigation. Altogether ten specimens of the new mineral were discovered, but the crystals employed in the determination of the morphological characters were taken from the best of them, four in number.

The Herminia mine and the Generosa mine, Sierra Gorda, Chili, are the localities given on the labels for nine of the specimens; the remaining specimen, which exhibits a few minute crystals of the new mineral in conjunction with native gold, comes from the Bolaco mine, San Cristóbal, Chili. The matrices are more or less decomposed, and one specimen in

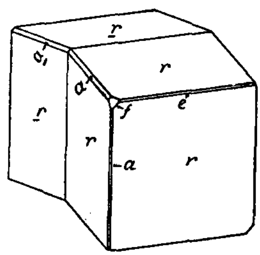

Fig. 1.
Paratacamite. Twinned crystal: Rhombohedral type.

particular is almost falling to pieces. In addition to quartz the associated minerals are galena and caracolite, both of which are much altered. The former has in places disappeared altogether, leaving a reticular arrangement of small square pits; the latter has no doubt been in part affected by the cleansing which the specimens had undergone before reaching the Museum, in order to rid them of the mud and dirt encasing them.

The types of crystals are two in number. In one, as has already been stated, the crystals resemble cubes but are really rhombohedra. Certain edges and corners are often truncated by small faces. Fig. 1 depicts such a rhombohedron twinned about one of its faces; similar crystals are very common. Crystals of the second type differ markedly in appearance from those of the first, and may easily, at a glance, be mistaken for atacamite. They are prismatic in form, being elongated parallel to the edge of a zone [*rfa*], and, since they are invariably twinned about the face of the form *r* lying in this prismatic zone, they simulate orthorhombic symmetry. Crystals of this kind are shown in figs. 2 and 3; the second individuals, which lie at the back and cannot be seen, are in every way similar to the first. When there are no re-entrant angles—and this is frequently the case—nothing suggests on ordinary inspection that these crystals are really twinned. The angles *rf* and *rc* are respectively 52° 55′ and 49° 48′; in the case of a crystal of atacamite, for which it might be mistaken, the angles *bm* and *be* are

56° 31½′ and 53° 1½′ [1]. The difference of a few degrees in the case of the corresponding angles is too small to be detected by the unaided eye. Crystals of atacamite, however, from this district usually show the form

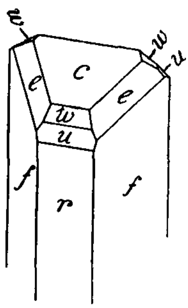

Fig. 2.

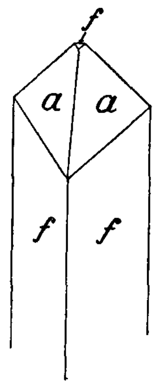

Fig. 3.

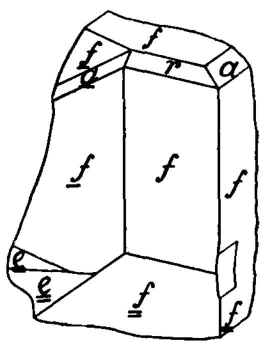

Fig. 4.

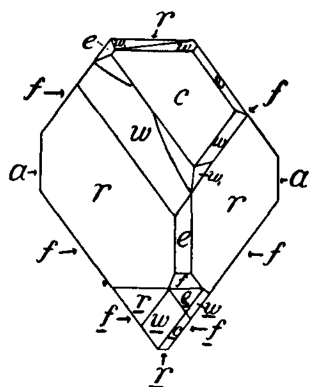

Fig. 5.

Paratacamite. Twinned crystals : Prismatic type.

h (132), which is invariably striated parallel to its intersection with *e* (011), and this form, if present, serves to discriminate the two minerals, since no form similarly striated is displayed by the new mineral.

There is a good cleavage parallel to the principal rhombohedron-

[1] These angles are taken from the author's paper, Min. Mag., 1898, vol. xii, pp. 15–25.

face *r*. Twins with respect to the same face are very common; indeed the prismatic type seems to be invariably twinned. Various types of twin-crystals are illustrated in figs. 1–5. The crystal drawn in fig. 4 is remarkable for the conjunction of three distinct individuals, the faces of which are denoted by letters with no bar, one bar, and two bars underneath respectively. The three contiguous faces of the form *f* are parallel and give on the goniometer a single image. The first and second individuals are related by the ordinary twinning about a face *r*. The first and third are in parallel positions, and possibly the latter may have arisen from independent twinning with respect to the second individual. Another plausible explanation is that a face of the form *a* is the twin-plane, although such a twin has not been otherwise observed. It may be remarked that the line of demarcation between the first and third individuals is parallel to the edge of a zone [*rfa*]. The crystal illustrated in fig. 5 is noteworthy for the vicinal planes accompanying the faces of the form *w*. In two cases it is quite a distinct face (lettered w_1), while in the third it gives an irregular intersection with the corresponding face *w*. The measurements from *c* of the three faces w_1, on this particular crystal relative to the corresponding face *w*, are as follows:—

	Azimuth.	Distance.
w_1	2°20′	29°16′
	0 59	29 15
	2 24	28 17
w	0 0	25 20

and the calculated values for a face of the form (411) are

(411)	0 0	30 37

Thus w_1 lies near the form (411), but so variable is its position on the various crystals measured that no definite symbols can be assigned to it. Its distance from the corresponding face *w* is fairly constant, greater variation occurring in the orientation.

The crystals are mostly small in size, rarely exceeding 2 mm. in any direction; often they are merely needles, less than 1 mm. in length and 0·5 mm. in cross-section.

The name paratacamite has been assigned to the new mineral, because, as the analysis given below shows, the percentage chemical composition is the same as that of atacamite. A certain connexion can be traced between the measurements on crystals of the two minerals made from the respective cleavage-faces, as appears from the following table:—

TABLE I.

Comparison between the Measurements on Paratacamite and Atacamite.

Paratacamite. Form.	Measured from *r* (100). Azimuth.	Distance.	Atacamite.[1] Form.	Measured from *b* (010). Azimuth.	Distance.
a $0\bar{1}1$	90° 0′	90° 0′	*c* 001	90° 0′	90° 0′
f $1\bar{1}1$	,, ,,	52 55	*e* 011	,, ,,	53 1½
r 001	41 49	82 49½	*u* 101	41 17½	90 0
e 101	,, ,,	41 25	*r* 121	,, ,,	45 11
a $10\bar{1}$	,, ,,	−48 35			
e 011	0 0	80 25	*a* 100	0 0	90 0
c 111	,, ,,	49 48	*m* 110	,, ,,	56 31½
f $\bar{1}11$	,, ,,	−63 6½			

Altogether forty-three crystals were measured on the three-circle form of goniometer[2] designed by the author, in every case the reference-pole being a face of the form *r*. In the case of six crystals, in which the face *c* is well developed, measurements were made from this face also, and on some crystals of the type illustrated in figs. 2 and 3 controlling measurements were made from faces of the form *f*.

The observed forms, nine in number, are as follows:—

Form.	Indices. Rhombohedral.	Hexagonal.	Characters, &c.
c	111	0001	Not always found: generally small, but occasionally large: images distinct.
r	100	$10\bar{1}1$	Occurs on every crystal: large in the rhombohedral type, the faces being distorted and the images consequently blurred, and small in the prismatic type, the images being distinct: a good cleavage parallel to faces of this form: twin-plane.
f	$11\bar{1}$	$02\bar{2}1$	Common: small, almost minute, on the rhombohedral type, and large on the prismatic type: images good.
e	110	$01\bar{1}2$	Common, but small: images distinct.
a	$10\bar{1}$	$11\bar{2}0$	Common: small and frequently much curved: in the latter case images are spread out and often lie an appreciable distance from the theoretical position.

[1] These values are taken from the author's paper, loc. cit.

[2] Min. Mag., 1899, vol. xii, pp. 175–182.

w	113	$0\bar{2}25$	Common, but small: often accompanied by vicinal planes: images poor.
v	229	$0.\bar{7}.7.13$	Rare and minute: images very faint.
u	115	$0\bar{4}47$	Rare and minute: images poor.
l	$31\bar{3}$	$24\bar{6}1$	Rare and minute: images poor.

The terms used to indicate the size of the faces must, of course, be interpretated relatively to the size of the crystals.

In Table II are compared the calculated values and the means of the observed azimuths and distances corresponding to the various forms, *r* being the reference-pole; the angles employed as the basis for the calculations are indicated by the asterisks. In Table III are given the calculated values, *c* being the reference-pole, together with the mean angles observed on the six crystals measured from this pole.

TABLE II.

Measurements from $r = (100) = (10\bar{1}1)$.

Form.	Indices.		Calculated Values.		Observed Means.		Number.	Limits of Observations.	
	Rhombohedral.	Hexagonal.	Azimuth.	Distance.	Azimuth.	Distance.		Azimuth.	Distance.
a	$01\bar{1}$	$\bar{1}2\bar{1}0$	*	*	90° 0′	90° 0′	26		90°20′
l	$13\bar{3}$	$\bar{2}6\bar{4}1$	,,	75°51½	,, ,,	75 56	5		75°42′ – 76 15
f	$11\bar{1}$	$02\bar{2}1$	,,	52 55	,, ,,	52 57	69		52 29 – 53 15
l	$3\bar{3}1$	$6\bar{4}\bar{2}1$	60°48′	−47 47	61 10	−47 41	2	61 7′, 61°13′	47 36, 47 46
r	010	$\bar{1}101$	41 49	*	41 53½	82 49½	74	41 7 – 42 37	81 56 – 83 28
e	110	$01\bar{1}2$	,, ,,	41 25	,, ,,	41 24	37	,, ,, ,, ,,	41 8 – 41 51
a	$1\bar{1}0$	$2\bar{1}\bar{1}0$	,, ,,	−48 35	,, ,,	−48 27	33	,, ,, ,, ,,	48 5 – 48 56
u	151	$\bar{4}407$	30 49	71 17½	30 15	71 14	1		
w	131	$\bar{2}205$	24 6	65 10	24 22	65 23	16	23 45 – 24 57	64 39 – 66 0
l	$3\bar{3}\bar{1}$	$6\bar{2}\bar{4}\bar{1}$	,, ,,	−52 20	,, ,,	−52 21	6	,, ,, – ,, ,,	51 30 – 52 56
e	011	$\bar{1}012$	*	80 25	0 0	80 30½	18		80 9 – 80 56
c	111	0001	,,	49 48	,, ,,	49 45	29		49 6 – 50 10
w	311	$20\bar{2}5$	,,	24 28	,, ,,	23 59½	14		23 11 – 24 39
v	922	$7.0.\bar{7}.13$	,,	17 7½	,, ,,	17 24	8		17 7 – 17 45
u	511	$40\bar{4}7$	,,	15 44	,, ,,	15 48	5		14 54 – 16 6
f	$1\bar{1}\bar{1}$	$20\bar{2}\bar{1}$	,,	−63 6½	,, ,,	−62 56½	41		62 25 – 63 41

Table III.

Measurements from c = (111) = (0001).

Rhombohedral; axis *c* = 1·0248.

Form.	Indices.		Calculated Values.		Observed Means.		Number.	Limits of Observations.	
	Rhombohedral.	Hexagonal.	Azimuth.	Distance.	Azimuth.	Distance.		Azimuth.	Distance.
a	$\bar{1}01$	$\bar{1}\bar{1}20$	30° 0′	90° 0′	30° 0′	90° 0′	2	30°23′	90° 5
l	$\bar{3}13$	$\bar{4}\bar{2}61$	19 6½	80 56	19 7	80 55	2	19° 0′, 19 14	80°50′, 81 0
f	$\bar{1}11$	$\bar{2}021$	0 0	67 5½	0 0	67 12	24		66 30 – 67 56
e	011	$\bar{1}012$	" "	30 37	" "	30 41	17		29 45 – 31 42
w	311	$20\bar{2}5$	" "	– 25 20	" "	– 25 31	6		25 5 – 25 49
v	922	$7{\cdot}0{\cdot}\bar{7}{\cdot}13$	" "	– 32 40½	" "	– 32 42	6		32 15 – 33 11
u	511	$40\bar{4}7$	" "	– 34 4	" "	– 33 45	3		33 32 – 33 55
r	100	$10\bar{1}1$	" "	– 49 48	" "	– 49 42	17		49 0 – 50 14

Perhaps the most interesting point connected with these crystals is the fact that the optical characters displayed by them are not in accordance with the apparent morphological symmetry. Unless crushed to minute fragments they do not give extinction between crossed nicols, and there is no noticeable variation in the intensity of the transmitted light. A few crystals were crushed in oil, and occasional fragments were observed which are approximately perpendicular to one of the optic axes characterizing a biaxial crystal, and give in convergent light a biaxial brush. The precise relation of these microscopic fragments to the crystalline arrangement could not be ascertained, since it was not found possible to grind a section thin enough for the purpose.

As may be expected from what has just been stated, paratacamite is apparently singly refractive as far as regards light refracted across a prism. An approximate determination of the index gave the value 1·846 for the green light which is transmitted by the crystals; light of longer wave-length is almost entirely absorbed in transmission across the smallest crystal available for this purpose. The value obtained is very near the mean index of atacamite.[1]

[1] loc. cit., p. 24.

Chemical Composition (G. T. P.).

Chemical analysis shows that the mineral is an hydrated oxychloride of copper having the same empirical formula as atacamite, viz.

$$CuCl_2.3Cu(OH)_2.$$

An analysis made on 0·5132 gram gave the following result:—

CuO	56·10
Cu	14·27
Cl	15·97
H_2O[1]	14·10
	100·44

The density (weight of 1 cc.) of the mineral is 3·74, as determined with a 3 cc. pyknometer on 0·7430 gram.

In the case of the oxychlorides of lead, paralaurionite and laurionite, which are also two minerals having the same percentage chemical composition[2], it was found that the latter mineral on ignition began to lose water at a lower temperature than the former. Experiment suggests that a similar relation subsists between paratacamite and atacamite. On heating at gradually increasing temperature up to 230° C. no change was produced in either mineral; but, after heating for about an hour at 250°, 0·0976 gram of atacamite began to blacken and lost about 2 mg. in weight, while paratacamite (0·1027 gram) still remained unchanged; continuing the heating for another hour at 260°, however, paratacamite just began to blacken and lost 0·5 mg., while atacamite lost an additional 2 mg. After heating for another hour at 280°, atacamite had lost altogether 5 mg. and paratacamite 4 mg.

Summary of Characters.

An hydrated oxychloride of copper, $CuCl_2.3\,Cu(OH)_2$. Pseudo-rhombohedral. Twins common, twin-plane *r*. Commonly in rhombohedra (*r*), or slender prismatic crystals elongated parallel to the edge of a zone [*rfa*]. Cleavage, *r* good. Fracture, conchoidal. Brittle. H. = 3, G. = 3·74. Lustre, vitreous. Colour, bright green, varying in shade according to the thickness. Streak, green. Refractive index, 1·846. Shows optical anomalies.

[1] From loss on ignition of a glass tube containing the mineral and a plug of dry sodium carbonate. A direct determination of the water made on 0·3464 gram by Penfield's method gave as low a percentage as 12·56, but there is reason to fear that some loss of water may have occurred.

[2] Min. Mag., 1899, vol. xii, p. 110.