CUBANITE FROM SUDBURY, ONTARIO

M. A. Peacock and G. M. Yatsevitch, *Harvard University,
Cambridge, Massachusetts.*

Summary

Excellent crystals of cubanite from Sudbury, Ontario, are orthorhombic, dipyramidal, with the forms: $c(001)$, $b(010)$, $a(100)$, $l(130)$, $m(110)$, $e(012)$ new, $y(011)$, $f(102)$, $g(101)$, $d(201)$, $t(112)$, $w(111)$, $o(122)$, $r(121)$, $p(131)$, on the preferred pseudo-hexagonal parameters of chalmersite: $a:b:c=0.5822:1:0.5611$ (Hlawatsch). Twins, common by reflection in (110); also by rotation through 119°35′ about [001]. Cleavage, none; $H=3\frac{1}{2}$; $G=4.101$ at 27°C; magnetic, highly susceptible along [010]. Analysis: Cu 22.88, Fe 41.41, S 35.35; sum 99.64, giving $CuFe_2S_3$. The identity of cubanite and chalmersite is confirmed. The name chalmersite should be dropped. It is suggested that the name barracanite may be revived for the mineral with composition $CuFe_2S_4$, if such exists.

The Harvard Mineralogical Museum recently received a specimen with excellent crystals of cubanite of novel appearance from the Frood Mine at Sudbury, Ontario. The specimen was collected in the course of an investigation of the ore deposits of that district, by the Department of Geological Research of the International Nickel Company of Canada, Limited. We are indebted to Dr. H. J. Fraser of the department for this interesting material and to the management of the company for courteous permission to publish our observations and the accompanying analysis. The crystallographic study is largely the work of the junior author; it was revised and completed by the senior author who has added the remaining material. Our thanks are due to Professor Charles Palache for the privilege of studying this material and for advising us in the course of the work, and to Professor L. C. Graton for reading the manuscript and suggesting some improvements.

Crystallography

The Sudbury cubanite is brassy yellow and the crystals are of substantial size, up to 5 mm. across, and not greatly elongated in any one direction. In this respect the Canadian crystals differ from the prismatic crystals of chalmersite[1] from the Morro Velho Mine at Minas Geraes in Brazil, described by Hussak (1902), Palache (1907) and Hlawatsch (1910). Some of the Sudbury crystals are thick basal tables somewhat elongated along the *b*-axis; some are flattened between a pair of parallel

---

[1] The investigations on *Cuban* (Breithaupt, 1843) and *Chalmersit* (Hussak, 1902) are examined by Zenzén (1925), who reaches the well-founded decision that the minerals decribed as cubanite or chalmersite are identical, and that cubanite has priority. The deciding observation is that of Kalb and Bendig (1923) who identified a polished section of Breithaupt's original material from Cuba with material from Tunaberg, Sweden, which has all the properties of the typical chalmersite from Brazil.

faces of the unit prism and slightly extended along the c-axis; and all of them are fully developed on their free sides in holohedral orthorhombic symmetry.

On the two-circle goniometer the crystals give excellent measurements in close agreement with the angles calculated by Hlawatsch from Palache's elements for Brazilian chalmersite in a new orientation. Palache retained the orientation of Hussak, which displayed a morphological analogy between cubanite and chalcocite but resulted in somewhat complicated indices. Hlawatsch interchanged the horizontal axes and took the plane (133) in Palache's notation as the parametral plane. Independently we have reached the same orientation as that of Hlawatsch, which is adopted with Professor Palache's approval. Considerations of morphological analogy may properly decide the arbitrary factors of orientation, such as the naming of the axes in the orthorhombic system; but such considerations should not interfere with the choice of morphological elements entirely proper to the species. If morphological relations exist between two species they may then appear more correctly in nearly aliquot relations of the corresponding elements rather than in near equality.

TABLE 1. CUBANITE. TWO-CIRCLE MEASUREMENTS ON EIGHT CRYSTALS

Forms	No. of faces	Measured		Calculated	
		ϕ	ρ	ϕ	ρ
c (001)	12	—	0°00′	—	0°00′
b (010)	8	−0°10′	90 00	0°00′	90 00
a (100)	3	90 00	90 00	90 00	90 00
l (130)	14	29 45½	90 00	29 47½	90 00
m (110)	11	59 49	90 00	59 47½	90 00
*e (012)	2	−0 04½	15 30	0 00	15 40½
y (011)	12	−0 01	29 17	0 00	29 18
f (102)	4	89 57	25 44	90 00	25 43½
g (101)	6	90 00	43 58½	90 00	43 56½
d (201)	2	90 05	62 53	90 00	62 34½
t (112)	1	59 36	29 09	59 47½	29 08½
w (111)	5	59 48	48 08	59 47½	48 07
o (122)	9	40 39	36 27	40 39	36 29
r (121)	20	40 40½	55 57	40 39	55 56½
p (131)	19	29 49	62 44½	29 47½	62 43½

* New form.

The transformation of the elements and symbols of cubanite is expressed by the following equations:

$a:b:c$ Hlawatsch—Peacock and Yatsevitch $= 1/3a:1:c/3a$ Hussak—Palache

$h\ k\ l$ Hlawatsch—Peacock and Yatsevitch $= k\ 3h\ l$ Hussak—Palache

Table 1 gives a summary of the measurements on selected crystals, with the symbols and calculated angles of Hlawatsch. The previous form letters have been retained, with the following desirable changes:

Pk. & Yat. . . . . . . $b\ a\ m\ l$
Hlaw. . . . . $a\ b\ l\ m$

All the described forms of cubanite were observed by us except:

$h(032)$ Hlaw. $= h(102)$ Pal., unpublished observation by a student.

$s(221)$ Hlaw. $= s(263)$ Pal., a well-established form.

$v(132)$ Hlaw. $= v(112)$ Hus., a presumed and unproved twin plane, never observed as a crystal form and therefore omitted from the form list.

$u(314)$ Hlaw. $= u(1.9.12)$ Pal. Hlawatsch (1910) suggested that this plane, observed only once, is possibly a face of the common form $o(122)$ twinned on (110) or (130). Re-examination of the Morro Velho crystals, on which the form u was reported, revealed evidence of twinning which was not previously noticed. On Professor Palache's suggestion the form is withdrawn.

Our measurements confirm the form $w(111)$, observed only by Hlawatsch, and $d(201)$, observed only by Palache and regarded by Hlawatsch as possibly representing $p(131)$ in twin position. One new form $e(012)$ was observed twice, with good small faces in fair position.

The principal forms of the Sudbury cubanite are: c, m, y, which determine the habit of the crystals. The base c is usually large and always striated parallel to [010] frequently in oscillatory combination with the macrodome f. The prism m is likewise present in large brilliant faces giving faultless reflections. The brachydome y is generally next in size and of excellent quality. Of secondary importance are b, l, a, g, f, p, r; the least important forms are d, o, w, e, t.

All our crystals are twins in which the planes (001) and (110) are common to the two individuals. On four twins the angle (010): $\overline{(010)}$ was found to range from 60°21′ to 60°27½′; mean 60°24½′. The calculated angle resulting from twinning by reflection in (110) is 60°25′. In most cases the composition surface is the plane (110); occasionally it is a surface near (1$\overline{3}$0). Twinning by reflection in (130), which would result in the calculated angle (010): $\overline{(010)} = 59°35′$, was not found. Twinning causes the striations on the co-planar bases of the twinned individuals to intersect at about 60°, whereby twinning is easily recognized in the rare cases in which obvious re-entrants are lacking. Most of the twins are binary contact twins on (110) (Figs. 3, 4); one fourling was measured

1

2

3

4a

5a

4b

5b
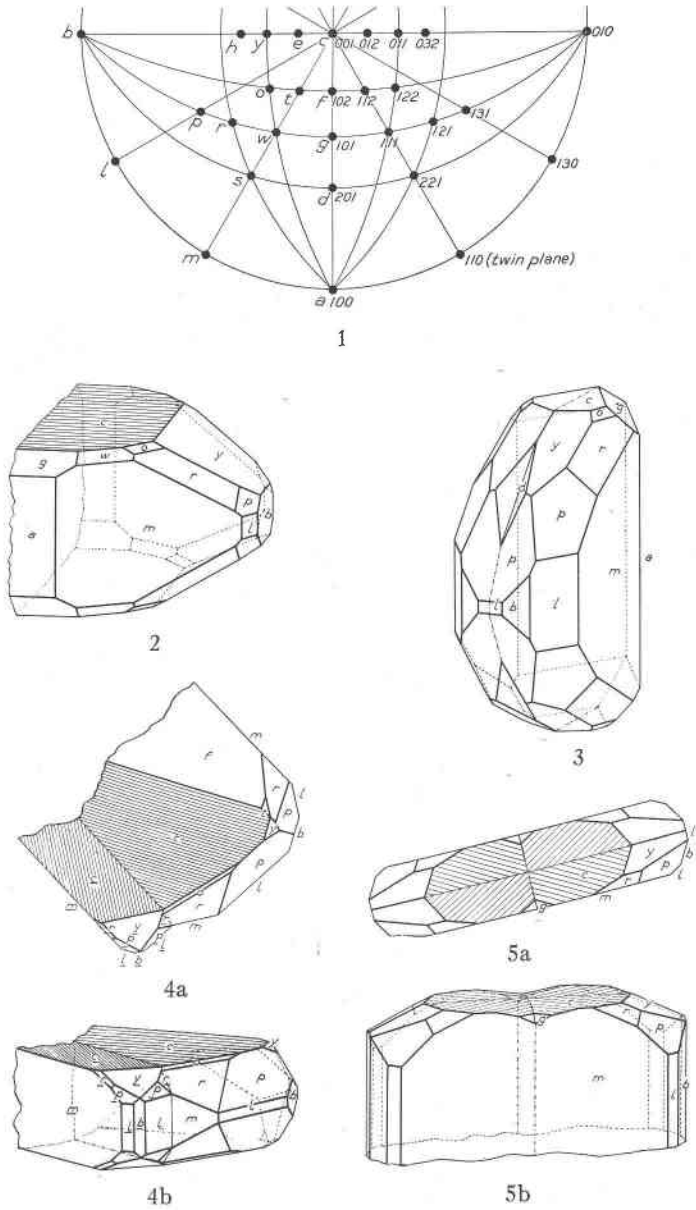
FIGS. 1–5. Cubanite. Stereographic projection of the accepted forms and
typical crystals from Sudbury, Ontario.

(figure 5) in which the diagonally opposite individuals are in parallel position while the four adjoining pairs are twins by reflection in (110), or by rotation through 119°35′ or 60°25′ about [001]. One imperfect sixling was observed on the matrix; the striations on the base of each individual make an angle of nearly 60° with those on its neighbours. Although it could not be measured, the sixling is evidently due to twinning on both (110) and (1̄10).

Twinning on (130) is implied by Hussak (1902) and Hlawatsch (1910), but in the absence of measurements it is evident that neither author attempted to distinguish between the geometrical relations resulting from twinning on (110) and on the quasi-normal plane (130). The difference in the two twinned positions, namely 0°50′, is much greater than the probable error with these excellent crystals. Still less trustworthy is Hussak's mention, without measurements, of twinning on a pyramidal plane, probably (112) Hussak = (132) Hlawatsch; we measured one such group and found it to be a random intergrowth.

Figure 1 is a stereographic projection of the established forms of cubanite. Figures 2–5 represent typical Sudbury crystals. Figure 2 illustrates a common type developed symmetrically about the b-axis; a small individual attached to the main crystal in twin position is omitted in the drawing. Figure 3 is a twin symmetrically developed about the twin plane m and flattened parallel to that plane. Figure 4 is an unsymmetrically developed twin on (110), tabular parallel to the base. Figure 5 is a simplified drawing of the fourling mentioned above.

Table 2 is an angle-table for the established forms of cubanite in the style recently proposed by one of us (Peacock, 1934, p. 252). The elements and angles for the inverted positions, with subscripts 1 and 2, are useful in the goniometric study of orthorhombic crystals in which, due to variability of habit, the vertical axis is not easily recognized.

Physical Properties

There is lack of agreement in the published data on the cleavage of cubanite (chalmersite). The massive mineral from Cuba and Sweden is described as having cubical cleavage (Breithaupt, 1843; Sjögren, 1882), on which insufficient ground the mineral was originally assigned to the isometric system. Kalb and Bendig (1923) report cleavage as (001) and (110) on Swedish material. On the Alaskan material one good cleavage is reported (Johnson, 1917). On the other hand, cleavage has not been observed on crystals (Hussak, 1902; Palache, 1907; Hlawatsch, 1910), except by Merwin, Lombard and Allen (1923), who broke one crystal from Brazil "squarely along the base." Despite careful trials we failed to obtain any cleavage from the Sudbury crystals; the fracture is

typically conchoidal. It is possible that the conspicuous cleavage in massive cubanite is in reality parting due to polysynthetic twinning on (110). The appearance of rectangular cleavage would result from repeated twinning after the type shown on a large scale by the fourling (figure 5). In such twinning the planes of parting would be the two nearly rectangular composition surfaces (110) and a surface near ($1\overline{3}0$). The lack of agreement on the basal cleavage is not explained.

TABLE 2. CUBANITE—$CuFe_2S_3$
Orthorhombic, dipyramidal
$a:b:c=0.5822:1:0.5611$; $p_0:q_0:r_0=0.9638:0.5611:1$
$q_1:r_1:p_1=0.5822:1.0376:1$; $r_2:p_2:q_2=1.7822:1.7176:1$

Forms	ϕ	$\rho=C$	ϕ_1	$\rho_1=A$	ϕ_2	$\rho_2=B$
c (001)	—	0°00′	0°00′	90°00′	90°00′	90°00′
b (010)	0°00′	90 00	90 00	90 00	—	0 00
a (100)	90 00	90 00	—	0 00	0 00	90 00
l (130)	29 47½	90 00	90 00	60 12½	0 00	29 47½
m (110)	59 47½	90 00	90 00	30 12½	0 00	59 47½
e (012)	0 00	15 40½	15 40½	90 00	90 00	74 19½
y (011)	0 00	29 18	29 18	90 00	90 00	60 42
h (032)	0 00	40 05	40 05	90 00	90 00	49 55
f (102)	90 00	25 43½	0 00	64 16½	64 16½	90 00
g (101)	90 00	43 56½	0 00	46 03½	46 03½	90 00
d (201)	90 00	62 34½	0 00	27 25½	27 25½	90 00
t (112)	59 47½	29 08½	15 40½	65 06½	64 16½	75 49
w (111)	59 47½	48 07	29 18	49 57½	46 03½	68 00
s (221)	59 47½	65 51	48 17½	37 57	27 25½	62 40
o (122)	40 39	36 29	29 18	67 13	64 16½	63 11
r (121)	40 39	55 56½	48 17½	57 20	46 03½	51 23½
p (131)	29 47½	62 43½	59 17	63 47½	46 03½	39 31½

The hardness of the Sudbury crystals is $3\frac{1}{2}$, which agrees with Hussak's observation on crystals from Brazil. Merwin, Lombard and Allen found the massive mineral to be harder than chalcopyrite, for which the hardness $3\frac{1}{2}$–4 is given; Sjögren gives the hardness as about 4, Breithaupt 5.

On a large, clean crystal of Sudbury cubanite Mr. Gonyer reports the specific gravity 4.101 at 27°C., using the silica glass pyknometer. On massive cubanite from Cuba the following values are given: 4.026–4.042 (Breithaupt, 1843); 4.18 (Smith, 1854); 4.169 (Stevens in Dana, 1892). Massive cubanite from Tunaberg, Sweden, gave 4.030 (Cleve,

(1873). Massive chalmersite from Alaska gave 4.04 (Johnson, 1917). On the original crystallized chalmersite from Brazil Hussak (1902) obtained the discordant value 4.680, probably on a minute sample since only 0.015 gm. was used for the corresponding analysis.

The Sudbury cubanite was found to be magnetic and highly susceptible only in the direction of the crystallographic b-axis (the a-axis of Hussak—Palache), which is evidently the greatest axis of a strongly elongated magnetic ellipsoid; this observation confirms that of Merwin, Lombard and Allen (1923) on Brazilian crystals of entirely different habit. Furthermore, this axis was found to have polarity with respect to a permanent magnet. This raised the question: is cubanite hemimorphic? It proved, however, that the magnetic polarity of a crystal was easily reversed in the field of an electro-magnet; the magnetic property therefore offers no evidence of asymmetry about (010).

Composition

Table 3 gives an analysis of the Sudbury cubanite compared with previous analyses of cubanite (chalmersite).

TABLE 3. Analyses of Cubanite (Chalmersite)

	1	2	3	4	5	6	7
Cu	22.88	22.27	23.52	23.57 .	24.32	22.96	23.4
Fe	41.41	43.13	41.14	41.24	41.15	42.51	41.2
S	35.35	35.11	35.30	36.00	34.37	34.78	35.4
	99.64	100.51	99.96	100.81	99.84	100.25[a]	100.0

1. Cubanite, Frood Mine, Sudbury, Ontario; analyst, International Nickel Co., H. Waern, Chief Chemist.

2. Chalmersite, Morro Velho Mine, Minas Geraes, Brazil; analyst Florence, on 0.0896 gm. crystals. Hussask (1906).

3. Chalmersite, Threeman Mining Company, Landlocked Bay, Prince William Sound, Alaska; analyst Allen. Johnson (1917).

4. Chalmersite, Tunaberg, Sweden; analyst Kalb and Bendig (1923).

5. Cubanite, Barracanao, Cuba; analyst Schneider (1895).

6. Cubanite, Cuba (Breithaupt's original material); analyst Schneidhauer (1845).

7. $CuFe_2S_3$.

[a] Incl. Pb, trace.

The new analysis agrees closely with previous analyses of materials from the type locality in Cuba, and from Sweden, Alaska and Brazil; and all the analyses compare well with the now accepted formula $CuFe_2S_3$. There thus remains no doubt as to the identity of well-described minerals named cubanite or chalmersite. One uncertainty, however, still remains. In Dana (1892, p. 79) there are four early analyses (1, 2, 3, 5 Dana's numbers) of a massive mineral from Cuba which accord much more nearly to the formula $CuFe_2S_4$, which was once ac-

cepted both for cubanite and for chalmersite.[2] In the absence of any descriptive details regarding the analyzed materials, and in view of the fact that none of the modern analyses comes close to the composition $CuFe_2S_4$, one may justly suspect the purity of the analyzed substances. If, however, further work should confirm the existence of an individual mineral with the composition $CuFe_2S_4$, it would be proper to follow Schneider (1895) and Doelter (1925) and name it barracanite.

REFERENCES

Breithaupt, A., 1843: Cuban, ein neuer, dem Weisskupfererz ähnlicher Kies. *Pogg. Ann.*, vol. **59**, pp. 325–327.
Cleve, P. T., 1873: Om mineralet Cuban. *Geol. Fören. Förh.*, vol. **1**, p. 105.
Dana, E. S., 1892: *System of Mineralogy*, 6 ed., New York.
Doelter, C., 1926: *Handbuch der Mineralchemie*, vol. 4(1), Dresden and Leipzig.
Hlawatsch, C., 1910: Bemerkungen zur Krystallform des Chalmersits und des Prehnits. *Zeit. Kryst.*, vol. **48**, pp. 205–209.
Hussak, E., 1902: Ueber Chalmersit, ein neues Sulfid der Kupferglanzgruppe von der Goldmine "Morro Velho" in Minas Geraes, Brasilien. *Centralb. Min.*, pp. 69–72.
———— 1906: Ueber die chemische Zusammensetzung des Chalmersit. *Centralb. Min.*, pp. 332–333.
Johnson, B. L., 1917: Preliminary note on the occurrence of Chalmersite, $CuFe_2S_8$, in the ore deposits of Prince William Sound, Alaska. *Econ. Geol.*, vol. **12**, pp. 519–525.
Kalb, G., and Bendig, M., 1923: Chalmersit von Tunaberg in Schweden. *Centralb. Min.*, pp. 643–646.
Merwin, H. E., Lombard, R. H. and Allen, E. T., 1923: Cubanite: identity with chalmersite; magnetic properties. *Am. Mineral.*, vol. **8**, pp. 135–138.
Palache, C., 1907: Mineralogical notes. *Am. Jour. Sci.*, vol. **24**, pp. 249–258.
Peacock, M. A., 1934: A suggested form of crystallographic presentation. *Am. Jour. Sci.*, vol. **28**, pp. 241–254.
Scheidhauer, C. H., 1845: Die chemische Zusammensetzung des Cubans. *Pogg. Ann.*, vol. **64**, pp. 280–281.
Schneider, R., 1895: Notiz über die Zusammensetzung und die Constitution des Cubans. *Jour. Prak. Chem.*, vol. **52**, pp. 555–559.
Sjögren, Hg., 1882: Chondrodit von Kafveltorp. *Zeit. Kryst.*, vol. **7**, pp. 113–152 (Cuban, p. 116).
Smith, J. L., 1854: Reëxamination of American Minerals: Part IV. *Am. Jour. Sci.*, vol. **18**, pp. 372–381.
Zenzén, N., 1925: Geschichtliches über Cuban(it) von Tunaberg nebst Bemerkungen über eine unberechtigte Namensänderung desselben in Chalmersit. *Geol. Fören. Förh.*, vol. **47**, pp. 385–389.

[2] By a curious error, Dana (1892, p. 79) gives the percentage proportions actually corresponding to $CuFe_2S_3$ as those for $CuFe_2S_4$.