CHINOITE, A NEW MINERAL

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ABSTRACT

Crystallographic studies of small, emerald-green crystals from the Chino pit, Chino Mines Division, Kennecott Copper Corporation, Santa Rita, New Mexico led to the description of a new mineral dimorphous with pseudomalachite.

X-ray studies by the Weissenberg method on the new mineral showed it to be orthorhombic and gave a space group Pnn—C_{2v}^{10} with cell dimensions $a_0=7.47$ Å, $b_0=8.31$ Å, $c_0=5.83$ Å. The axial ratio, calculated from the *x*-ray cell dimensions, $a:b:c=0.8989:1:0.7016$. The unit cell contents are $Cu_{10}(PO_4)_4(OH)_8=2Cu_5(PO_4)_2(OH)_4$.

Crystal forms present are $b\{010\}$, $m\{110\}$, $n\{011\}$. The polar ratio, $p_0:q_0:r_0=0.7858:0.7046:1$. The axial ratio, calculated from the goniometric measurements, $a:b:c=0.8967:1:0.7046$.

Cleavage is {110}, perfect; fracture, irregular; hardness, 5–6; luster, adamantine to vitreous; color, dark emerald-green; diaphaneity, transparent to translucent; tenacity, brittle. The calculated specific gravity is 5.24; the measured specific gravity is 5.22.

The optical data are: $n_X=1.698$, $n_Y=1.745$, $n_Z=1.793$; 2V is close to 90°; optically (+); $X=c$.

INTRODUCTION

In the Spring of 1950, through the courtesy of Mr. G. J. Ballmer, Superintendent of Mines, a dark emerald-green, encrusting copper mineral (Fig. 1) from the Chino pit copper mine, Chino Division, Kennecott Copper Corporation, Santa Rita, New Mexico, was given to the University of New Mexico for identification. The mineral was found by Mr. William Baltosser, Mine Engineer of the Chino pit, in some fissures between two quartz monzonite dikes, 100 feet below the 6165 bench. This particular area of the pit is a highly altered section where the disseminated copper ore runs 0.5–1.0 percent. Mr. Ballmer and Mr. Baltosser believed the mineral probably was one of the more common supergene green copper minerals, and requested the mineralogy laboratory of the University of New Mexico to make the distinction. Supergene minerals are not abundant at Santa Rita. Kerr et al. (1950) report the presence of cuprite, melaconite, native copper, chrysocolla, malachite, and azurite, as well as smithsonite, in the supergene zone. No other unquestioned secondary phosphates have been reported from this locality. The occasional report of turquoise in this area has never been verified.* Apatite occurs as a primary accessory mineral in both the unaltered and altered granodiorite country rock and is the probable source of the phosphate radical in the new mineral.

* Personal communication from Mr. Ballmer.

FIG. 1. Chinoite crystals on altered quartz monzonite rock. ×50.

When it became apparent, from preliminary studies, that we were dealing with a new mineral, Mr. Baltosser generously donated specimens from his private collection in order that a complete study could be made.

The writers are indebted to the late Samuel G. Gordon and Dexter H. Reynolds for scientific aid and advice given during this study.

The new mineral has been named *Chinoite* (pronounced Chee′-no-ite) after the location in which it was found.

PHYSICAL PROPERTIES

A specific gravity determination was made by means of a microchemical analytical balance, first weighing the crystal in air and then in carbon tetrachloride. This procedure was necessitated by the small size of the crystals, which range up to 1 mm. in length, and by the fact that not enough material could be sacrificed for a pycnometer determination. The crystal used in the specific gravity determinations weighed 6.26 mg. in air, 3.17 mg. in CCl_4, from which a specific gravity of 5.22 was indicated, a close check with the theoretical value, 5.24.

The cleavage of chinoite is perfect parallel to the prism {110}; fracture, irregular; hardness, 5–6; luster, adamantine to vitreous; color, dark emerald-green; diaphaneity, transparent to translucent; tenacity, brittle.

Structural Crystallography

The good crystals of chinoite were highly suitable for single crystal study. Rotation and Weissenberg x-ray pictures were taken around all three crystallographic axes using CuK_α radiation. The Weissenberg films indicated rigorously orthorhombic symmetry, and the extinctions were characteristic for the space group $Pnn—C_{2v}{}^{10}$. The cell dimensions, checked by the powder x-ray method, are: $a_0 = 7.47$ Å, $b_0 = 8.31$ Å, $c_0 = 5.83$ Å. The axial ratio, calculated from the x-ray cell dimensions, $a:b:c = 0.8989:1:0.7016$.

X-ray Powder Pattern

The x-ray powder pattern of chinoite is shown in Fig. 2, along with a powder pattern of pseudomalachite. The pseudomalachite powder picture was made from a sample loaned by Dr. Clifford Frondel, Harvard University (Holden Collection, #537, Rheinbreitbach, Rhine Province, Germany). The estimated intensities and the measured θ and d values for chinoite are given in Table 1. The pattern has been indexed as far as $\theta = 29.12°$, and the measured values agree with one or more theoretical values. The powder pattern of pseudomalachite was measured and calculated by Berry (1950). A comparison of the strongest lines of chinoite and pesudomalachite are given in Table 2.

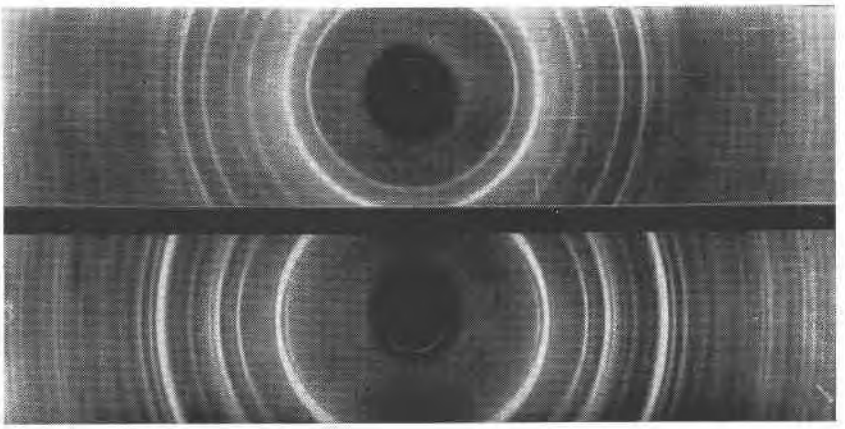

Fig. 2. *X*-ray powder patterns of chinoite (top) and pseudomalachite (bottom).

Morphological Crystallography

Five separate crystals of chinoite were used for the measurement of interfacial angles. Four of these crystals were mounted with the c-axis parallel to the axis of the goniometer head, and the fifth was successively

TABLE 1. CHINOITE *X*-RAY POWDER PATTERN

Orthorhombic, *Pnn*; $a=7.47$ Å, $b=8.31$ Å, $c=5.83$ Å

I	θ(Cu)	*d* (meas.)	(*hkl*)	*d* (calc.)	*I*	θ (Cu)	*d* (meas.)	(*hkl*)	*d* (calc.)
8	7.59°	5.83 Å	(001)	5.83 Å	1	24.32°	1.87 Å	(113)	1.86 Å
10	9.22	4.80	(011)	4.77				(400)	1.87
1	10.66	4.16	(020)	4.16				(141)	1.89
7	11.89	3.74	(200)	3.74	1	25.25	1.80	(210)	1.82
8	15.32	2.91	(002)	2.92				(312)	1.81
			(211)	2.88				(240)	1.82
9	16.98	2.63	(130)	2.60	2	26.68	1.71	(123)	1.71
3	17.59	2.55	(112)	2.57				(411)	1.70
5	18.49	2.43	(022)	2.39				(331)	1.73
4	19.42	2.31	(202)	2.30				(241)	1.72
			(131)	2.36				(042)	1.69
			(301)	2.29				(420)	1.70
			(330)	2.33	2	27.46	1.67	(213)	1.68
1	21.74	2.08	(231)	2.06	2	28.30	1.62	(051)	1.60
			(040)	2.08				(150)	1.62
2	23.60	1.92	(013)	1.89	2	29.12	1.58	(223)	1.58
			(132)	1.94				(402)	1.57

I	θ (Cu)	*d* (meas.)	*I*	θ (Cu)	*d* (meas.)
1	29.72	1.55	1	35.85	1.35
1	31.35	1.51	1	36.80	1.31
1	31.90	1.48	1	37.50	1.28
1	32.45	1.46	1	38.45	1.24
1	33.92	1.43	1	44.40	1.10
1	34.85	1.38	1	45.50	1.08

TABLE 2. COMPARISON OF THE STRONGEST POWDER *X*-RAY LINES OF CHINOITE AND PSEUDOMALACHITE

Chinoite			Pseudomalachite		
I	θ(Cu)	*d*(meas.)	*I*	θ(Cu)	*d*(meas.)
8	7.59°	5.83 Å	10	9.92°	4.48 Å
10	9.22	4.80	5	12.87	3.46
7	11.89	3.74	6	18.55	2.42
8	15.32	2.91	8	18.85	2.39
9	16.98	2.63	5	19.38	2.32
5	18.49	2.43	5	20.19	2.23
4	19.42	2.31	5	26.5	1.73

mounted with each of the three crystallographic axes parallel to the axis of the head. The faces were macroscopically excellent and gave good to poor optical reflections. Figure 3 illustrates a typical crystal of chinoite. Table 3 summarizes the goniometer data. The average of the measured angles agrees closely with the calculated angles. The axial ratio calculated from the goniometric measurements is in agreement with the axial ratio calculated from the x-ray cell dimensions.

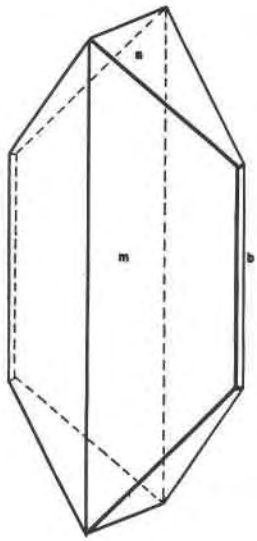

FIG. 3. Chinoite, clinographic projection showing the forms $b\{010\}$, $m\{110\}$, and $n\{011\}$.

TABLE 3. CHINOITE: CRYSTAL MEASUREMENTS, FIVE CRYSTALS

$a:b:c=0.8967:1:0.7046$ $\quad p_0:q_0:r_0=0.7858:0.7046:1$

Form	Number of Faces	Quality	Average Measured		Range		Calculated	
			Phi	Rho	Phi	Rho	Phi	Rho
$b\{010\}$	6	Poor to Fair	0°00′	90°00′	—	—	0°00′	90°00′
$m\{110\}$	18	Fair to Good	48 07	90 00	47°50′–48°16′	—	48 03	90 00
$n\{011\}$	10	Fair to Good	0 00	35 10	—	34°49′–35°25′	0 00	35 03

COMPOSITION AND CELL CONTENT

A chemical analysis of the mineral chinoite is given in Table 4. The chemical analysis gives the empirical formula, $Cu_5(PO_4)_2(OH)_4$ or $2Cu(OH)_2 \cdot Cu_3(PO_4)_2$. Thus chinoite is dimorphous with pseudomalachite (Berry, 1950). The chemical analysis combined with the measured

specific gravity (5.22) and the cell dimensions (Table 1) gives the number of molecules in the unit cell, namely, two, from which the following structural formula for chinoite is obtained:

$$Cu_{10}(PO_4)_4(OH)_8 = 2Cu_5(PO_4)_2(OH)_4.$$

The specific gravity calculated for this structural formula is 5.24.

TABLE 4. CHINOITE: COMPOSITION AND CELL CONTENT

Constituent	Percent	Molecular Ratio	Empirical Formula	Ideal Cell Content
CuO	69.09	5.025	$Cu_5(PO_4)_2(OH)_4$	
P_2O_5	24.33	1.000	or	2
H_2O	6.57	2.068	$2Cu(OH)_2 . Cu_3(PO_4)_2$	
	99.99			

0.2399 gm. analyzed. Matthew E. Carlisle, analyst.

OPTICAL PROPERTIES

The optical properties of chinoite, as determined by the immersion method, are: $n_X = 1.698$, $n_Y = 1.745$, $n_Z = 1.793$; 2V is close to 90°; optically (+); X = *c*. The optical properties of verified pseudomalachite are cited by Berry (1950) as: $n_X = 1.785 - 1.80$, $n_Y = 1.835 - 1.86$, $n_Z = 1.845 - 1.88$; $2V = 46° - 50°$; $c \wedge X = 21° - 23°$.

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