CLINOCHALCOMENITE, A NEW MINERAL OF SELENITE

Lo Keding (雒克定), Wei Jun (魏 均),
Zhang Jingyi (张静宜) and Gu Qifang (顾绮芳)
(Beijing Uranium Geology Research Institute)

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Clinochalomenite was discovered by X-ray examination of its powder patterns. Then data on its single-crystal were collected and its chemical composition was determined by the electronic microprobe. Its physical and optical properties were determined by crystallographic study. A series of studies showed that clinochalcomenite is a new mineral of hydrated selenite of copper. Its chemical composition is identical, with that of chalcomenite, but they are different in X-ray powder pattern, crystallographic system, space group and optical properties. Clinochalcomenite and chalcomenite should, therefore, be isomeric, so the new mineral is named clinochalcomenite.

I. Occurrence

Clinochalcomentite was found in an oxidized zone at a place where uranium was also discovered. The palce is in Gansu Province, China. The mineral is found in a fracture zone in a carbonaceous siliceous slate of $D_2'S_6g_5$ (the Sanhe Formation of the Devonian system), which is widely distributed in the region.

Clinochalcomenite is closely associated with volborthite, chalcomenite, umangite and malachite. Volborthite occurs in a crystal, filmy form on the surface of the ore. Crystals of chalcomenite are well-developed on the walls of cavities. Powdery umangite and small crystals of clinochalcomenite were found in cavities. At the same time, umangite in small needlelike form was also found in the cavities.

II. Crystal Habit

The crystal of clinochalcomenite is small (Fig. 1), usually 0.2—0.3 mm long, with the longest one being 0.5—0.6 mm. Crystals are long prisms formed along the *c*-axis. There are longitudinal striations parallel to the *c*-axis in the prismatic faces.

Two crystals about 0.5 mm long were measured by the Goldschmidt-two-circle reflection goniometer, and it indicates that clinochalcomenits belongs to the monoclinic system of the rhombic prismatic class. The chief forms are rhombic prisms $m\{110\}$, $n\{210\}$, $e\{011\}$; pinacoids $a\{100\}$, $b\{010\}$, $c\{001\}$, $d\{101\}$. Among them rhombic prisms $\{110\}$ and $\{011\}$ are the most developed and the orthopinacoid $a\{100\}$, the less developed one. An angle table for clinochalcomenite is given in Table 1, crystal habits are shown in Fig 2.

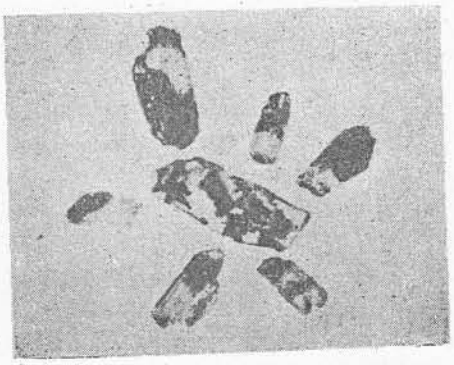

Fig. 1. Prismatic crystals of clinochalcomentite (black — inclusions of umangite).

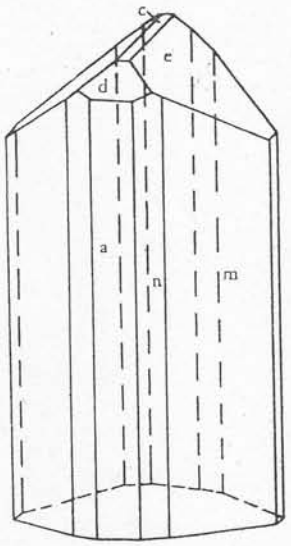

Fig. 2. Chinochalcomenite forms: $a\{100\}$, $c\{001\}$, $d\{101\}$, $e\{011\}$ $m\{110\}$, $n\{210\}$.

Table 1

Angle Table for Clinochalcomenite

$a : b : c = 0.9976 : 1 : 0.7405$; $\beta = 95°35'$; $p_0 : q_0 : r_0 = 0.7423 : 0.7369 : 1$;
$r_1 : p_1 : q_1 = 1.3570 : 1.0073 : 1$; $\mu = 84°25'$; p_0' 0.7459; q_0' 0.7405; x_0' 0.0942.

Forms	φ	ρ	φ_2	$\rho_2 = \beta$	C	A
a 100	90°00′	90°00′	0°00′	90°00′	84°19′	0°00′
b 010	0°00′	90°00′	—	0°00′	90°00′	90°00′
c 001	90°00′	5°41′[a)]	84°19′	90°00′	0°00′	84°19′
m 110	46°37′	90°00′	0°00′	46°37′	85°52′	43°23′.
e 011	10°20′	36°31′	82°26′	54°15′	35°48′	83°53′
d 101	90°00′	40°02′[a)]	49°58′	90°00′	34°21′	49°58′
n 210	64°25′	90°00′	0°00′	64°25′	84°49′	25°35′

a) The errors of goniometry for the prismatic faces of forms c and d are bigger than those for the others, because they are very small and of bad quality. Moreover, each of these two forms was met only once in our study. $\rho_{001} = 7°16'$ and $\rho_{101} = 42°48'$ were calculated from unit-cell parameters obtained with the four-circle diffractometer. The errors of the rest forms are within 30′.

III. Physical and Optical Properties

Clinochalcomenite is transparent and blue-green in colour, but sometimes the colour of some crystals turns black, because they contain inclusions of umangite. It is brittle, glassy lustre, of hardness No. 2 and perfect cleavage {110}. The measured by the suspension method and calculated specific gravities are respectively 3.28 and 3.42.

In transmitted light, clinochalcomenite is light blue-green. Pleochroism Ng—blue-green; N_m, N_p—colourless. Positive elongation. Uniaxial negative. The indices of refraction are: N_g—1.765, N_m—1.723, N_p—1.675. Birefringence: $N_g - N_p = 0.090$. $(-)2V = 78°$. Dispersion of optical axes $r < V$. As shown in Fig. 3 $b \| N_m$, $c \wedge N_g = 10°$, $a \wedge N_g = 3°$.

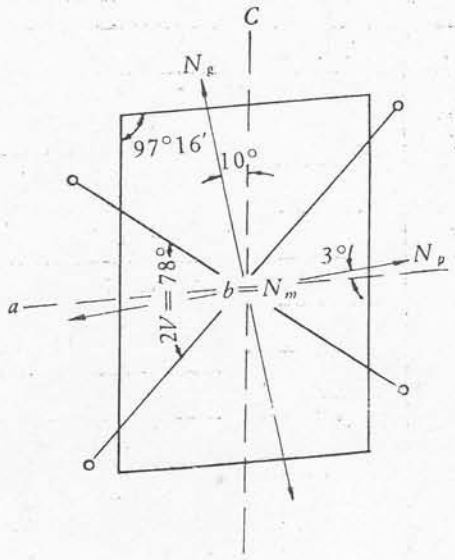

Fig 3. Optical orientation for clinochalcomenite.

IV. X-ray Diffraction Study

By oscillation and Weissenberg method the X-ray single-crystal of clinochalcomenite has been studies on b and c axes respectively. Indexes were derived from Weissenberg films *hol*, *hko* and systematic absence of reflection with *hol*: $h + l = 2n$, of reflection with $0k0$: $k = 2n$, which represents the monoclinic system of clinochalcomenite with diffraction symbol $2/mP2_1/n$, space group $c_{2h}^5 = P2_1/n$, unit-cell parameters $a_0 = 8.177$Å, $b_0 = 8.611$Å, $c_0 = 6.290$Å, $\beta = 97°16'$, $V = 439.34$Å^3, $Z = 4$. The unit-cell were determined with the four-circle diffractometer by Wu Bomu (伍伯牧) of the Institute of Biophysics, Academia Sinica.

For comparison, crystallographic data for clinochalcomenite and similar minerals (chalcomenite, ahlfeldite, cobaltomenite, synthetic $Zn[SeO_3]\cdot 2H_2O$) that have been reported in related literature are listed in Table 2.

Table 2

Comparison of Crystallographic Data Between Clinochalcomenite and Related Selenite Minerals

Name	Clinochalcomenite	Chalcomenite[1]	Ahlfeldite[2]	Cobaltomenite[3]	Synthetic[4]
Formula	$Cu[SeO_3]\cdot 2H_2O$	$Cu[SeO_3]\cdot 2H_2O$	$Ni[SeO_3]\cdot 2H_2O$	$Co[SeO_3]\cdot 2H_2O$	$Zn[SeO_3]\cdot 2H_2O$
System	Monoclinic	Ortnorhombic	Monoclinic	Monoclinic	Monoclinic
Space group	$P2_1/n$	$P2_12_12_1$	$P2_1/n$	$P2_1/n$	$P2_1/n$
Unit-cell parameters	$a_0 = 8.177$Å $b_0 = 8.611$Å $c_0 = 6.290$Å $\beta = 97°16'$	$a_0 = 6.671$Å $b_0 = 9.193$Å $c_0 = 7.384$Å	$a_0 = 7.53$Å $b_0 = 8.76$Å $c_0 = 6.43$Å $\beta = 99°05'$	$a_0 = 6.59$Å $b_0 = 8.73$Å $c_0 = 7.58$Å $\beta = 98°30'$	$a_0 = 6.43$Å $b_0 = 8.80$Å $c_0 = 7.65$Å $\beta = 98°00'$
Z	4	4	4	4	4

Table 3

X-ray Powder Data for Clinochalcomenite[a)]

No.	*hkl*	*I*	$d_{meas.}$	$d_{calc.}$
1	110	10	5.89	5.90
2	$10\bar{1}$	2	5.27	5.28
3	101	2	4.73	4.67
4	020	1	4.32	4.31
5	200	7	4.06	4.06
6	120	5	3.78	3.80
7	210	9	3.66	3.67
8	$12\bar{1}$ $21\bar{1}$	4	3.33	3.34 3.33
9	121	1	3.15	3.17
10	211	1	3.05	3.02
11	012	8	2.926	2.933
12	130	7	2.694	2.706
13	310 221	6b	2.570	2.580 2.578
14	$12\bar{2}$ $31\bar{1}$	7	2.482	2.485 2.492
15	301	4	2.361	2.374
16	311 320	3	2.280	2.288 2.290
17	040	5	2.145	2.153
18	013 132	2b	2.008	2.022 2.002
19	103	1	1.949	1.956
20	240	1	1.903	1.901
21	411 $42\bar{1}$	7	1.818	1.819 1.817
22	$22\bar{3}$	1	1.780	1.779
23	$31\bar{3}$ 213	2	1.725	1.724 1.727
24	$24\bar{2}$ $34\bar{1}$	3	1.659	1.668 1.659
25	151 402	1	1.616	1.616 1.611
26	250 341	5b	1.586	1.585 1.595
27	303 004	4	1.551	1.556 1.560
28	501 $41\bar{3}$ $20\bar{4}$	2	1.524	1.524 1.529 1.522
29	$21\bar{4}$ 233 511	5b	1.498	1.499 1.502 1.501
30	$12\bar{4}$	1	1.467	1.474
31	$35\bar{1}$ 060	3b	1.430	1.436 1.435
32	124 530	1	1.409	1.414 1.412
33	$13\bar{4}$	1	1.393	1.380
34	$32\bar{4}$ $50\bar{3}$ $43\bar{3}$	3b	1.360	1.359 1.366 1.366
35	423	3b	1.300	1.304
36	044 $10\bar{5}$	2	1.260	1.263 1.258
37	015	1	1.228	1.235
38	612 $31\bar{5}$ $55\bar{1}$	2	1.178	1.176 1.181 1.180
39	$70\bar{1}$ $62\bar{3}$	2	1.164	1.166 1.161
40	$54\bar{3}$ 710	2	1.151	1.153 1.148
41	$25\bar{4}$	2	1.138	1.140
42	225	2	1.110	1.113
43	$70\bar{3}$	2b	1.073	1.071
44		1	1.038	
45		1	1.024	
46		1	1.013	
47		1	1.005	
48		1b	0.9891	

a) Analyst: Tan Falan (谭发兰). Rad. Fe K_α; filter M_n; camera 57.3 mm, 30 kV, 14 ma, 10 hr.

$d_{meas.}$	$d_{calc.}$
1.551	1.556
	1.560
1.524	1.524
	1.529
	1.522
1.498	1.499
	1.502
	1.501
1.467	1.474
1.430	1.436
	1.435
1.409	1.414
	1.412
1.393	1.380
1.360	1.359
	1.366
	1.366
.300	1.304
.260	1.263
	1.258
228	1.235
178	1.176
	1.181
	1.180
164	1.166
	1.161
51	1.153
	1.148
38	1.140
0	1.113
3	1.071
3	

na, 10 hr.

It is clear from the table that the crystallographic properties of clinochalcomenite are obviously different from those of chalcomenite. Clinochalcomenite belongs to the monoclinic system with space group $P2_1/n$; chalcomenite belongs to the orthorhombic system with space group $P2_12_12_1$. Therefore, they are apparently two different minerals. Table 2 also shows that clinochalcomenite, ahlfeldite, cobaltomenite and synthetic $Zn(SeO_3)\cdot 2H_2O$ all belong to the monoclinic system with the same space group $P2_1/n$, and their unit-cell parameters are also approximately similar, thus they can be considered as being isostructural.

The X-ray powder patterns of clinochalcomenite were obtained. The X-ray powder data for clinochalcomenite and the d-spacings indices based on its single-crystal diffraction data are listed in Table 3.

The data in Table 3 indicate clearly that the calculated d-spacings for clinochalcomenite are in agreement with the measured ones. Furthermore, the X-ray powder data for clinochalmenite are not similar to those of chalcomenite.

V. Chemical Composition

The chemical composition of clinochalcomenite was determined by the JXA-50A electronic microprobe, and chalcomenite was used as a standard specimen.

The theoretical value of the chemical composition of chalcomenite is Cu 28.05% and the Se 34.86%. The X-ray relative intensities of the components elements of chalcomenite were calculated by the program USA-Magic IV. The calculated results are Cu 28% and Se 30% (25KV, 35°). The standard specimen chalcomenite was analyzed by the electronic microprobe. The result of analysis shows that the X-ray relative intensities of copper and selenium for standard specimen are Cu 28% and Se 32.4%, agreeing in the main with the theoretical values of those elements in chalcomenite.

On the basis of the above results of measurement, clinochalcomenite and the standard specimen of the chalcomenite were simultaneously analyzed by the electronic microprobe. This analysis shows that except selenium and copper, no other elements were found in the sample of clinochalcomenite. Selenium and copper are distributed homogeneously in the mineral (Figs. 4—6). The selenium and copper contents in both clinochalcomenite and the standard specimen of chalcomenite are very nearly the same. When the electronic beams of the electronic microprobe bombard the two minerals, they both foam at once. They are also quite similar in the number and the size of foaming. Because no other easily volatile elements exist in the samples, the phenomenon of foaming can be considered as caused by the water they contained. The above mentioned analyses indicate that clinochalcomenite and chalcomenite $Cu[SeO_3]\cdot 2H_2O$ are not only identical in the elements they contain, but are also very close to each other in the percentages of the two elements in them. Furthermore, the formulas of ahlfeldite and cobaltomenite that are isostructural with the mineral are $X[SeO_3]\cdot 2H_2O$ (X stands for the sort of metal cation). So the formula of clinochalcomenite should be identical with those of chalcomenite, ahlfeldite etc. It can be written as $Cu[SeO_3]\cdot 2H_2O$.

The research on clinochalcomenite has barely begun, because the quantity of clinochalcomenite and chalcomenite available for chemical analyses is too small and the further study of the mineral is sure to come. It is just a matter of time.

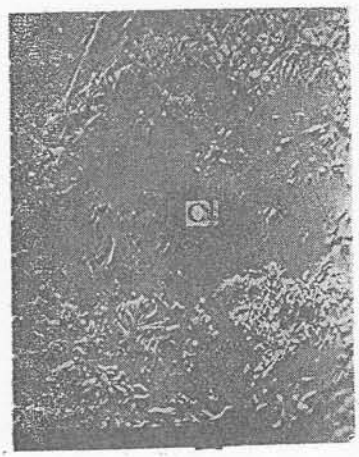

Fig. 4. BEI of specimen Cl-clinochalcomenite, Um-umangite.

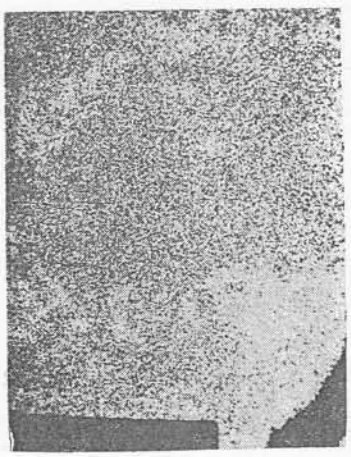

Fig. 5. X-ray image of selenium.

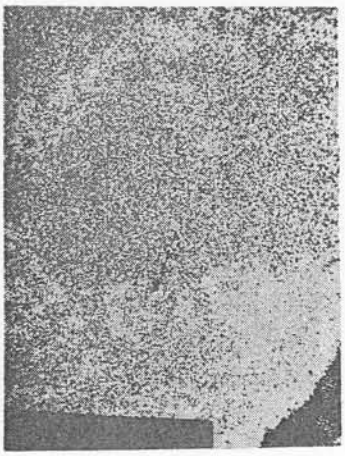

Fig. 6. X-ray image of copper.

Table 4

Electronic Microprobe Analyses for Clinochalcomenite and Chalcomenite[a)]

	Clinochalcomenite		Chalcomenite	
			Standard Specimen	Theoretical Value
Relative intensity (%)	Cu	29.68	28	
	Se	32.6	32.4	
K-factor	Cu	1.001	1.001	
	Se	1.163	1.163	
Content (%)	Cu	29.68	28	28.05
	Se	37.91	37.90	34.86

a) Analyst: Zhang Yi (张宜). 25 kV, 35°.

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