

## Cuprohydromagnesite and cuproartinite, two new minerals from Gabbs, Nevada

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### Abstract

Cuprohydromagnesite and cuproartinite were found with other secondary copper minerals in the brucite zone of the Basic Refractories Mine at Gabbs, Nye County, Nevada.

Cuprohydromagnesite,  $(\text{Cu,Mg})_2(\text{CO}_3)_2(\text{OH})_2 \cdot 4\text{H}_2\text{O}$ , occurs as a supergene alteration product of primary copper sulfides and magnesite-brucite-serpentine rock. Associated minerals include chalcopyrite, bornite, magnesite, antigorite, chlorite, brucite, hydromagnesite, artinite, huntite, alumohydrocalcite, callaghanite, mcguinnessite,<sup>1</sup> and nakauriite. The translucent blue crystals are bladed, elongated along the *c* axis and flattened on {010}. Cuprohydromagnesite is monoclinic, space group  $P2_1/c$ ,  $a = 10.653(3)$ ,  $b = 9.141(1)$ ,  $c = 8.570(2)\text{Å}$ ,  $\beta = 115^\circ 23'$ ,  $Z = 2$ . The strongest lines in the X-ray powder pattern are 6.54(25)(110), 5.91(100)(011), 3.393(40)(121), 2.954(60)(022), 2.573(25)(230), 2.408(30)(400), 2.247(40)(023), and 2.050(30)( $\bar{3}14$ ). Cuprohydromagnesite is biaxial (+),  $2V = 36-38^\circ$ ;  $\alpha = 1.562(2)$ ,  $\beta = 1.567(2)$ ,  $\gamma = 1.614(2)$ .  $G(\text{meas}) = 2.548(5)$ ,  $G(\text{calc}) = 2.543$ . The name is for the composition and the relation to hydromagnesite.

Cuproartinite,  $(\text{Cu,Mg})_2(\text{CO}_3)(\text{OH})_2 \cdot 3\text{H}_2\text{O}$ , occurs as a supergene alteration phase directly associated with cuprohydromagnesite. Crystals are acicular, blue translucent, elongated on {010} as radiating fiber aggregates. It is monoclinic, space group  $C2$ ,  $a = 16.899(2)$ ,  $b = 3.272(1)$ ,  $c = 6.362(2)\text{Å}$ ,  $\beta = 100^\circ 40'$ ,  $Z = 2$ . The strongest lines in the X-ray powder pattern are 8.30(4)(200), 5.51(8)( $\bar{2}01$ ), 3.800(5)( $\bar{4}01$ ), 2.813(10)(111), 2.283(3)( $\bar{5}11$ ), and 1.919(3)( $\bar{7}11$ ). Cuproartinite is biaxial (-),  $2V = 70-73^\circ$ ,  $\alpha = 1.544(2)$ ,  $\beta = 1.596(2)$ ,  $\gamma = 1.627(2)$ .  $G(\text{meas})$  is 2.186(5),  $G(\text{calc})$  is 2.188. The name is for the composition and the relation to artinite.

### Introduction

In 1970 one of the authors (SGO) found a richly mineralized supergene zone near the contact of primary copper sulfides and magnesite-brucite-serpentine rock in one of the abandoned brucite pits at the Basic Refractories Mine near Gabbs, Nye County, Nevada. Primary minerals include chalcopyrite, bornite, antigorite, magnesite, brucite, and chlorite. Associated minerals in the supergene zone are hydromagnesite, artinite, huntite, alumohydrocalcite, callaghanite, mcguinnessite, and nakauriite. In the supergene zone several small crystals of a blue bladed mineral and a light blue acicular mineral were found intimately associated with hydromagnesite and artinite. Further investigation indicated that these miner-

als were the copper-dominant analogues to hydromagnesite and artinite.

The names, cuprohydromagnesite and cuproartinite, are for the compositions and their relationships to hydromagnesite and artinite. Both species and their names have been approved by the Commission on New Minerals and Mineral Names, IMA. Type material has been deposited in the Smithsonian Institution (NMNH #144188) and in the collections of the Carnegie Museum of Natural History.

### Occurrence

Cuprohydromagnesite occurs as 0.5-5mm crystals as part of a supergene alteration zone. Cuproartinite, found as small (0.1-2mm) acicular crystals, occurs in direct association with cuprohydromagnesite, usually with hydromagnesite and artinite. The mines at Gabbs have been actively mined since 1937, first for brucite and later for magnesite (Cleveland, 1963).

<sup>1</sup> Mcguinnessite,  $(\text{Mg,Cu})_2\text{CO}_3(\text{OH})_2$ , is a new mineral recently approved by the IMA Commission on New Minerals and Mineral Names.

The magnesium deposits are located in the upper dolomite member of the Triassic Luning Formation, and were formed by the dissolution of dolomite beds by hydrothermal solutions which migrated upward and recrystallized as massive replacement bodies of magnesite. The magnesite units were then subjected to complex folding, faulting, low-grade regional metamorphism, dolomitization, and intrusion by dikes, sills, and a granodiorite stock. The igneous intrusion formed two small bodies of brucite and minor tactite zones around the dikes and sills. Tertiary block faulting, uplift, and erosion exposed the ore bodies.

### Cuprohydromagnesite

#### Physical properties

Cuprohydromagnesite occurs as bladed crystals, elongated along the  $c$  axis and flattened on  $\{010\}$  as sprays, crusts, and powdery coatings. Principal forms include  $\{001\}$ ,  $\{010\}$ , and  $\{310\}$  (Fig. 1). Indices were obtained by goniometric measurements. The crystals are brittle with a perfect  $\{010\}$  cleavage. Crystals have a vitreous to silky luster, are translucent, and pale blue to blue in color. The color intensity increases with increasing copper content. Mohs hardness is approximately  $3\frac{1}{2}$ . The streak is white.

Cuprohydromagnesite is biaxial (+), refractive indices (NaD)  $\alpha = 1.562(2)$ ,  $\beta = 1.567(2)$ ,  $\gamma = 1.614(2)$ ,  $2V = 36\text{--}38^\circ$ . It is weakly pleochroic with  $\alpha =$  colorless to pale blue,  $\beta =$  pale blue,  $\gamma =$  pale blue to light blue. Optical orientation is  $b = Z$ ,  $c:X = 48^\circ$ .

Specific gravity was determined in toluene on a Berman balance by averaged repeated measurements on 16mg of material;  $G(\text{meas})$  is 2.548(5),  $G(\text{calc})$  is 2.543. The specific gravity was calculated using a value of  $Z = 2$ , based on the mineral's isostructural relationship with hydromagnesite. Cuprohydromagnesite gives off a light blue fluorescence under short-wave ultraviolet radiation.

#### X-ray crystallography

Unit-cell parameters from Weissenberg and precession photographs using  $\text{CuK}\alpha$  radiation (1.54051Å) (estimated standard deviations in parentheses) are  $a = 10.653(3)$ ,  $b = 9.141(1)$ ,  $c = 8.570(2)$ ,  $\beta = 115^\circ 23'$ ,  $Z = 2$ ,  $V = 753.97\text{Å}^3$ . Lattice parameters were obtained from a least-squares refinement. The cell parameters are comparable to those of hydromagnesite, which is monoclinic,  $P2_1/c$ ,  $a = 10.11$ ,  $b = 8.94$ ,  $c = 8.38\text{Å}$ ,  $\beta = 114^\circ 35'$ ,  $Z = 2$  (Bariand *et al.*, 1973). The space group of cuprohydromagnesite

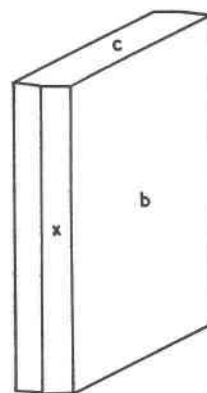


Fig. 1. Morphological development of cuprohydromagnesite. Forms are  $b = \{010\}$ ,  $c = \{001\}$ ,  $x = \{310\}$ .

is  $P2_1/c$ . Systematic extinctions were observed for  $\{0k0\}$  with  $k = 2n + 1$  and for  $\{h0l\}$  with  $l = 2n + 1$ . The powder data (Table 1) are comparable to those of hydromagnesite (JCPDS Card No. 25-513).

Twinning, which is almost constant in hydromagnesite, is present in cuprohydromagnesite but to a lesser extent. A prominent pseudo-orthorhombic cell of space group  $B22_12$  is present in hydromagnesite and has been used by previous researchers (Murdoch, 1954; Bariand *et al.*, 1973) to index the powder data. A pseudo-orthorhombic cell is present in cuprohydromagnesite but, like the twinning, it is poorly developed.

#### Chemical analysis

An electron microprobe analysis (Table 2) was used in the identification of cuprohydromagnesite, due in part to the lack of sufficient material for a standard chemical analysis. The analysis was conducted with 150 nA specimen current and 12 kV excitation voltage. Microprobe standards used for the following elements are: Cu, Fe (analyzed Cu-Fe-Ni alloy); Mg (magnesite); Ca (calcite).  $\text{CO}_2$  was measured by gravimetric analysis using absorption tubes and acid decomposition. Water was measured by total weight loss on ignition minus the  $\text{CO}_2$  content. The presence of  $\text{CO}_2$ ,  $\text{H}_2\text{O}(+)$ , and  $\text{H}_2\text{O}(-)$  was confirmed by DTA, TGA, and DTG analysis. Corrections were made using the EMPADR VII program of Rucklidge and Gasparrini (1969). Tests for Mn, Ti, Zn, Na, K, F, and Cl were negative. The mineral is readily soluble in most mineral acids.

Normalization of the analysis (Table 2, analysis 1) yields the empirical formula  $(\text{Cu}_{3.872}\text{Mg}_{1.596}\text{Fe}_{0.026}\text{Ca}_{0.007})(\text{CO}_3)_{8.890}(\text{OH})_{2.220} \cdot 3.884\text{H}_2\text{O}$ , based on 5 total cations. This yields the ideal formula unit of

Table 1. X-ray powder data for cuprohydromagnesite

$d_{\text{obs}}$	$d_{\text{calc}}$	hkl	I
9.63	9.625	100	20
6.63	6.628	110	25
5.91	5.908	011	100
4.810	4.812	200	5
4.570	4.570	010	10
4.281	4.283	$\bar{1}02$	5
4.259	4.258	210	10
4.130	4.129	120	5
3.870	3.871	002	10
3.565	3.565	012	15
3.393	3.393	121	40
3.312	3.314	220	10
3.250	3.247	211	5
3.151	3.154	102	5
2.980	2.982	112	10
2.954	2.954	022	60
2.901	2.905	130	5
2.832	2.835	031	5
2.767	2.766	221	20
2.690	2.689	113	5
2.610	2.611	131	5
2.600	2.596	122	5
2.573	2.574	230	25
2.533	2.533	202	15
2.482	2.484	013	5
2.408	2.406	400	30
2.287	2.285	040	5
2.247	2.247	023	40
2.222	2.223	140	10
2.213	2.215	222	5
2.195	2.196	113	20
2.190	2.191	132	10
2.141	2.142	204	5
2.085	2.085	214	10
2.050	2.049	314	30
2.029	2.027	123	15
2.018	2.016	142	5

114.6 mm Debye-Scherrer camera using CuK $\alpha$  radiation. Intensities visually estimated.

(Cu,Mg) $_6$ (CO $_3$ ) $_4$ (OH) $_2$ ·4H $_2$ O where Cu > Mg. The material is thus the copper-dominant analogue of hydromagnesite. Copper substitution varies from 3.02 to 3.70 of the 5 total cation sites in analyzed materials. Although the mineral has a variable composition, in all studied specimens (6) the copper content is well over 50 mole percent of the total cation site. An electron microprobe study of 20 hydromagnesite crystals from the same area shows some Cu substitution for Mg, but never over 10 atom percent of the total 5 cations. Thus there does not appear to be a complete series from hydromagnesite to cuprohydromagnesite. The name of cuprohydromagnesite is for material with Cu > Mg.

### Discussion

The crystal structure of hydromagnesite has been solved based on the pseudo-orthorhombic cell of the

mineral. In the structure, the magnesium sites are composed of 4(MgCO $_3$ ) + Mg(OH) $_2$  in the asymmetric unit. Both magnesium atoms are octahedrally coordinated, to form a three-dimensional framework of MgO $_6$  octahedra and triangular carbonate ions (Akao *et al.*, 1974). Judging from the difference between Mg-O (or OH) distances in these sites, preferential substitution of Cu for Mg into the MgCO $_3$  sites is highly probable. Thus the taxonomical boundary drawn between hydromagnesite and cuprohydromagnesite at Cu:Mg = 1:1 appears to be meaningless. The preferential substitution of copper for magnesium is verified by the electron microprobe analyses, none of which show a copper substitution of greater than 4 of the 5 total cation sites.

### Cuproartinite

#### Physical properties

Cuproartinite occurs as crusts of acicular crystals, elongated on {010}, and as spherical aggregates of radiating fibers. Principal forms include {001}, {100}, {010}, and  $\bar{2}$ 01. The crystals are brittle with a perfect {100} cleavage. Crystals have a vitreous to silky luster, are translucent, and pale blue to blue (the color intensity varies with the copper content). Mohs hardness is approximately 2½. The streak is white.

Cuproartinite is biaxial (-), refractive indices (NaD)  $\alpha$  = 1.544(2),  $\beta$  = 1.596(2),  $\gamma$  = 1.627(2),  $2V$  = 70–73°. It is weakly pleochroic with axial colors  $\alpha$  = colorless,  $\beta$  = colorless to pale blue,  $\gamma$  = pale blue. Optical orientation is  $b = Y$ ,  $c:Z = +31^\circ$ .

Specific gravity was determined in toluene on a Berman balance by averaged repeated measurements

Table 2. Chemical analysis of cuprohydromagnesite

	1	2	3
CuO	45.43	40.62	-----
FeO	0.27	0.28	-----
MgO	10.90	13.44	43.10
CaO	0.06	0.19	-----
CO $_2$ *	29.01	30.10	37.64
H $_2$ O**	15.12	15.79	19.26
TOTAL	100.79	100.42	100.00

1,2) Gabbs, Nye County, Nevada.

3) Theoretical hydromagnesite.

\* Measured by gravimetric analysis using absorption tubes and acid decomposition.

\*\* H $_2$ O measured by total weight loss on ignition minus analyzed CO $_2$  content.

on crystals weighing 12mg;  $G(\text{meas})$  is 2.186(5),  $G(\text{calc})$  is 2.188. The specific gravity was calculated using a value of  $Z = 2$ , based on the isostructural relationship with artinite. Cuproartinite gives off a pale blue fluorescence under short-wave ultraviolet radiation.

#### X-ray crystallography

Unit-cell parameters from a Weissenberg and precession study using  $\text{CuK}\alpha$  radiation (1.54051Å) (estimated standard deviations in parentheses) are  $a = 16.899(2)$ ,  $b = 3.272(1)$ ,  $c = 6.362(2)$ Å,  $\beta = 100^\circ 40'$ ,  $Z = 2$ ,  $V = 345.7\text{Å}^3$ . Lattice parameters were obtained from a least-squares refinement. The cell parameters are comparable to those of artinite, which is monoclinic, space group  $C2$ ,  $a = 16.56$ ,  $b = 3.15$ ,  $c = 6.22$ Å,  $\beta = 99^\circ 9'$ ,  $Z = 2$ . The space group of cuproartinite is  $C2$ . The only extinctions observed were those corresponding to the  $C$ -centered lattice,  $h + k = 2n$ . The powder data (Table 3) are comparable to those of artinite (JCPDS Card No. 6-484).

Table 3. X-ray powder data for cuproartinite

$d_{\text{obs}}$	$d_{\text{calc}}$	hkl	I
8.30	8.30	200	40
6.25	6.25	001	20
5.51	5.509	201	80
4.60	4.602	201	10
4.15	4.152	400	10
3.800	3.798	$\bar{4}01$	50
3.122	3.122	202	15
2.900	2.898	111	20
2.813	2.815	111	100
2.753	2.754	402	10
2.300	2.301	402	5
2.291	2.294	602	5
2.283	2.283	511	30
2.196	2.198	312	10
2.101	2.097	511	5
2.082	2.084	003	10
1.940	1.938	203	10
1.919	1.918	711	30
1.900	1.899	802	5
1.762	1.762	512	5
	1.763	711	5
1.720	1.720	113	5
1.681	1.684	$\bar{1}0, 01$	5
1.590	1.590	204	5
1.581	1.583	021	5
1.570	1.568	221	5
1.541	1.542	221	5
1.500	1.502	421	5

114.6 mm diameter Debye-Scherrer camera using  $\text{CuK}\alpha$  radiation. Intensities visually estimated.

Table 4. Chemical analysis of cuproartinite

CuO	40.99	34.35	-----
MgO	11.54	15.96	41.00
CaO	0.43	0.17	-----
$\text{CO}_2^*$	17.16	18.44	22.37
$\text{H}_2\text{O}^{**}$	29.46	30.40	36.63
TOTAL	99.58	99.32	100.00

1,2) Gabbs, Nye County, Nevada.

3) Theoretical artinite,  $\text{Mg}_2\text{CO}_3(\text{OH})_2 \cdot 3\text{H}_2\text{O}$ .

\* Measured by gravimetric analysis using absorption tubes and acid decomposition.

\*\*  $\text{H}_2\text{O}$  measured by total weight loss on ignition minus analyzed  $\text{CO}_2$  content.

#### Chemical analysis

An electron microprobe analysis (Table 4) was used in the identification of cuproartinite, due in part to the lack of sufficient material for a conventional chemical analysis. The analysis was conducted as described for cuprohydromagnesite. Tests for Mn, Ti, Zn, Fe, Na, K, F, and Cl were negative. The mineral is readily soluble in most mineral acids.

Based on two total cations, the analyzed material (Table 4, analysis 1) yields the empirical formula of  $(\text{Cu}_{1.257}\text{Mg}_{0.700}\text{Ca}_{0.043})(\text{CO}_3)_{0.963}(\text{OH})_{2.094} \cdot 2.949\text{H}_2\text{O}$ . This yields an ideal formula of  $(\text{Cu},\text{Mg})_2(\text{CO}_3)(\text{OH})_2 \cdot 3\text{H}_2\text{O}$  where  $\text{Cu} > \text{Mg}$ . The material is thus the copper-dominant analogue to artinite. Copper substitution in all studied material (5 specimens) is variable, ranging from 52 to 63 atom percent of the cation site. Electron microprobe analysis of ten artinites from the area show only a partial substitution of Cu for Mg (maximum of 10 atom percent). Thus, as with cuprohydromagnesite, a complete solid solution series does not appear to be present.

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