MOORHOUSEITE AND APLOWITE, NEW COBALT MINERALS FROM WALTON, NOVA SCOTIA

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ABSTRACT

Moorhouseite and aplowite are new supergene cobalt sulphate minerals from Walton, Nova Scotia. Moorhouseite, $CoSO_4.6H_2O$, is monoclinic with $a = 10.0$ Å, $b = 7.2$, $c = 24.3$, $\beta = 98°22'$, $Z = 8$, S.G. 1.97 (meas.), 2.006 (calc.). *X*-ray spectrographic analysis gave Co:Ni:Mn:Cu:Fe:Zn = 100:45:21:9:6:1. The mineral has very small $(-)2V$, $\alpha = 1.470$, $\gamma = 1.496$.

Aplowite, $CoSO_4 \cdot 4H_2O$, is monoclinic with $a = 5.94$ Å, $b = 13.56$, $c = 7.90$, $\beta = 90°30'$ calculated from the powder pattern; $Z = 4$, S.G. 2.33 (meas.), 2.359 (calc.). *X*-ray spectrographic analysis gave Co:Mn:Ni:Cu:Fe:Zn = 100:50:45:3:2:2. The refractive indices are 1.528 (min.), 1.536 (max.). Both aplowite and moorhouseite are pink, water-soluble, and give *x*-ray powder patterns identical to their synthetic equivalents.

INTRODUCTION

Aplowite, $CoSO_4.4H_2O$, and moorhouseite, $CoSO_4.6H_2O$ are new minerals discovered on material collected by Boyle during his investigation of the geology of the Walton-Cheverie area of Nova Scotia (Boyle, 1963). The cobalt sulphates occur at the Magnet Cove Barium Corporation mine, which is about $2\frac{1}{2}$ miles southwest of Walton. The Magnet Cove property is the largest producer of barite in Canada and in addition has an associated high-grade lead-zinc-copper-silver orebody which has recently been developed and brought into production.

Aplowite and moorhouseite occur together as closely associated water-soluble patchy efflorescences on a $2'' \times 4'' \times 8''$ specimen containing various sulphides in a barite-siderite matrix. The sample was wrapped in the field in several layers of polyethylene and examined by *x*-ray immediately after unwrapping. No change in the minerals has been detected after more than a year of exposure in the laboratory. Detailed mineralogical studies of the Magnet Cove deposit have indicated that colloform cobaltian and nickelian pyrite occurs abundantly and is the most probable source of the supergene cobalt sulphates.

MOORHOUSEITE

Crystallographic properties

The theoretical formula of moorhouseite is $CoSO_4.6H_2O$ and as such the mineral is a new member of the hexahydrite group comprising

hexahydrite ($MgSO_4.6H_2O$), bianchite ($ZnSO_4.6H_2O$), and ferrohexahydrite ($FeSO_4.6H_2O$). Additional artificial isomorphous members are known.

The minerals of the hexahydrite group are monoclinic, prismatic. Artificial $CoSO_4.6H_2O$ is easily precipitated from aqueous solutions; crystals are thick tabular {001}. Morphological data are given in Groth (1908). Rotation, *n*-level Weissenberg, and precession photographs about *a* and *c* obtained from a crystal grown at 55° C. gave $a = 10.0$Å, $b = 7.2$, $c = 24.1$, β 98°39′, space group $C2/c$ or Cc. These results are in good agreement with those obtained in the crystal structure study by Zalkin *et al.* (1962): $a = 10.032$Å, $b = 7.233$, $c = 24.261$, $\beta = 98°22'$. With morphological *c* doubled, the *x*-ray cell compares as follows:

$$a:b:c = 1.387:1:3.354,\ \beta\ 98°22'\ (x\text{-ray})$$
$$a:b:c = 1.396:1:3.381,\ \beta\ 98°43'\ (\text{morph}).$$

X-ray powder data for moorhouseite and synthetic $CoSO_4.6H_2O$ are given in Table 1. The measured *d*-spacings and visually estimated intensities were obtained from films taken with a 57.3 mm. diameter camera and filtered iron radiation.

Physical and optical properties

Moorhouseite is pink (close to Ridgeway's light pinkish cinnamon), and has a vitreous lustre, white streak, conchoidal fracture, and a hardness of $2\frac{1}{2}$. A specific gravity of 1.97 was obtained from natural material by suspension in heavy liquids. Pure synthetic $CoSO_4.6H_2O$ has a measured S.G. of 2.00–2.04, and a calculated S.G. of 2.006 based on unit cell contents of $8(CoSO_4.6H_2O)$ and the lattice constants obtained by Zalkin *et al.*, (1962).

In transmitted light, moorhouseite is granular to fine-grained columnar with pale pink colour and pleochroism. The mineral is biaxial negative with $\alpha = 1.470$, $\gamma = 1.496$, $(-)2V$ 20° ± 10° and absorption $X \gg Z$. Although the indices of synthetic material are slightly variable, the crystal used for the *x*-ray study gave α 1.471, β 1.496, γ 1.497, $(-)2V$ very small, $Y = b$.

Chemical data

It was impossible to obtain sufficient moorhouseite for a complete chemical analysis, but approximately 6 mg. of hand picked material were used for *x*-ray spectrographic analysis. As moorhouseite is easily soluble in water, the cations were determined by *x*-ray spectroscopy of aqueous solutions using the ratio method outlined in Jambor, Lachance, & Courville (1964). The cation atomic ratio was found to be Co:Ni:Mn:

TABLE 1. *X*-RAY POWDER DATA FOR SYNTHETIC $CoSO_4.6H_2O$ AND MOORHOUSEITE
Indexing based on dimensions given by Zalkin *et al.* (1962)

I/est	$CoSO_4.6H_2O$ *d* meas	Moorhouseite *d* meas	*d* calc	*hkl*
2	5.84 Å	5.84 Å	5.85 Å	$1\bar{1}0$
3	5.45	5.45	5.44	$\bar{1}12$
1	5.08	5.08	5.09	$11\bar{2}$
1	4.95	4.94	4.96, 4.93	$\bar{2}00$, $\bar{1}13$
1	4.85	4.84	4.84	$\bar{2}02$
1/2	4.57	4.54	4.54	$1\bar{1}3$
10	4.37	4.39	4.38, 4.37	$\bar{1}14$, $20\bar{2}$
4	4.12	4.13	4.13	$\bar{2}04$
6	4.01	4.01	4.02, 4.00	$1\bar{1}4$, 006
1	3.86	3.87	3.88	$\bar{1}15$
3	3.58	3.59	3.58, 3.58	$20\bar{4}$, $02\bar{1}$
1	3.45	3.45	3.46, 3.44	$02\bar{2}$, $\bar{1}16$
1	3.36	3.36	3.36	$\bar{2}06$
1	3.18	3.18	3.18	$11\bar{6}$
1/2	—	3.10	3.10	$02\bar{4}$
2	3.01	3.01	3.01, 3.01, 3.00	$3\bar{1}0$, $\bar{3}12$, 008
5	2.91	2.91	2.91	$20\bar{6}$
1/2	2.83	2.84	2.84, 2.83	$\bar{3}14$, $31\bar{2}$
1/2	2.79	2.80	2.79	$\bar{2}22$
1/2	—	2.71	2.72, 2.72	$\bar{2}24$, $\bar{3}15$
1	2.681	2.679	2.683	$02\bar{6}$
1	2.584	2.589	2.581	$11\bar{8}$
1	2.506	2.506	2.509, 2.503	$\bar{1}19$, $\bar{4}02$
1/2	2.421	2.411	2.417	$20\bar{8}$
1/2	2.306	—	2.309	$02\bar{8}$
2	2.271	2.276	2.270, 2.269	$13\bar{3}$, $22\bar{6}$
1/2	2.206	2.210	2.208	$\bar{1}34$
1/2	2.057	2.059	2.060, 2.058, 2.053	$\bar{2}29$, $\bar{4}22$, $\bar{1}36$
2	1.999	2.001	2.000, 2.000, 1.996	00.12, 0.2.10, 318
1/2	1.970	1.963		
1/2	1.927	1.930		
1/2	1.906	1.908		
2	1.870	1.870		
1/2	1.848	—		
1	1.809	1.813		
1	1.770	1.767		
	1.757			
1	1.725			

Cu:Fe:Zn = 100:45:21:9:6:1. Traces of Si, Mg and Ca were found by optical spectrography. The formula is thus essentially (Co,Ni,Mn) $SO_4.6H_2O$, or theoretically, $CoSO_4.6H_2O$. The artificial nickel analogue is also known, and it is proposed that in natural materials the name moorhouseite be applied to the appropriate hexahydrates with Co dominant. The mineral is named for W. W. Moorhouse, Professor of Geology in the University of Toronto.

APLOWITE

The theoretical formula is $CoSO_4.4H_2O$. The mineral is closely associated with moorhouseite, occurring as patchy efflorescences and as coatings next to the rock surface, beneath moorhouseite.

Properties

Aplowite has a pink colour (Ridgeway's La France pink) which is much brighter than that of moorhouseite. The mineral has a white streak, vitreous lustre, and a hardness of about 3. *X*-ray spectrographic analysis on about 2 mg. gave the following atomic ratio for the cations: Co:Mn:Ni:Cu:Fe:Zn = 100:50:45:3:2:2. Optical spectrography showed traces of Mg, Si, Ag, and Ca. The cation ratio, compared to that given for moorhouseite above, indicates that aplowite did not form by dehydration of the associated hexahydrate.

In transmitted light, aplowite is very finely granular and weakly tinted pink. Because of the small grain size and complexly intergrown nature, the optical characteristics of the mineral could not be well-defined. The measured refractive indices 1.528 (min.), 1.536 (max.), are considerably lower than those obtained from artificial material prepared by dehydration of $CoSO_4.6H_2O$ — $n_{min.}$ 1.533, $n_{max.}$ 1.546. The lower refractive indices obtained for the Walton mineral possibly result from the substitution of abundant Mn.

Larsen & Glenn (1920) report that artificial $CoSO_4.6H_2O$ dehydrates rapidly on exposure to air to form a pentahydrate with α 1.531, β 1.549, γ 1.552. They also report that material formed by dehydration of $CoSO_4.6H_2O$ in a desiccator has the following optical properties:

$\alpha = 1.529 \pm 0.003$ oisine-pink
$\beta = 1.546 \pm 0.003$
$\gamma = 1.548 \pm 0.003$ pale rose pink
Pleochroism faint; $(-)2V$ medium

In this laboratory, dehydration of $CoSO_4.6H_2O$ invariably led to the formation of the tetrahydrate. The refractive indices of the latter material correspond well with the above data given by Larsen & Glenn, and under these circumstances, it is suggested that their optical data may characterize $CoSO_4.4H_2O$. However, additional study of synthetic aplowite is clearly required in order to delineate its optical properties and establish the effects of minor element substitution—particularly manganese. Although various tetrahydrates can be directly precipitated from aqueous solutions, we have unfortunately had little success in crystallizing such material in this laboratory.

X-ray data

As the *x*-ray powder pattern of aplowite is essentially identical to that of artificial $CoSO_4.4H_2O$ (Table 2), it is evident that the mineral is a new member of the tetrahydrate sulphate group of which $MnSO_4.4H_2O$, $FeSO_4.4H_2O$, and $MgSO_4.4H_2O$ are known to occur in nature. By analogy

TABLE 2. *X*-RAY DATA FOR ARTIFICIAL $CoSO_4.4H_2O$ AND APLOWITE FROM WALTON, NOVA SCOTIA
Camera diameter 57.3 mm. Indexing based on *a* 5.94, *b* 13.56, *c* 7.90 Å, β 90°30′, space group $P2_1/n$.

$CoSO_4.4H_2O$ Filtered Fe radiation		Aplowite Filtered Cu radiation			
I est	*d* meas		*d* meas	*d* calc	*hkl*
3	6.81 Å	4	6.78 Å	6.78 Å	020
9	5.45	9	5.44	5.44	110
3	4.76	2	4.73	4.73	101
10	4.47	10	4.46	4.47, 4.46	120, 111
6	3.94	8	3.95	3.95	002
1/2	3.60	1	3.59	3.60	130
7	3.39	6	3.39	3.39	040
2	3.20	5	3.22	3.22, 3.21	$\bar{1}12$, 112
6	2.95	7	2.95	2.95, 2.94	$\bar{1}22$, 140
1/2	2.765	1	2.765	2.763, 2.755	$\bar{1}41$, 141
1/2	2.713		2.716	2.720, 2.716, 2.712	220, 211, 050
2	2.561	4	2.563	2.566, 2.565	221, 051
1	2.513				
1	2.460	1/2	2.466	2.467	$\bar{1}50$
1	2.409	2	2.413	2.415	$\bar{1}03$
2	2.350	3	2.353	several possible	
2	2.259	3	2.260	2.262, 2.260	$\bar{1}23$, 060
		1/2	2.131	2.130	$\bar{1}33$
1/2	2.095	1/2	2.105	2.109, 2.096, 2.095	$\bar{2}32$, 152, 232
1/2	2.055	1/2	2.040	2.042, 2.039	$\bar{1}61$, 161
2	1.963	3	1.965	1.967, 1.962, 1.959, 1.959	$\bar{1}43$, 062, 310, 143
1/2	1.938	1/2	1.937		
1	1.881	2	1.883		
1/2	1.858				
1/2	1.809				
1	1.790	2	1.791		
1	1.749	1	1.759		
1/2	1.716	1	1.722		
1	1.670	1	1.668		
1	1.647				
1	1.621	1	1.630		
1/2	1.569	1/2	1.566		
2	1.505	2	1.508		

to the unit cell data of the iron member of the group, aplowite is monoclinic, space group $P2_1/n$, with the following unit cell dimensions calculated from the *x*-ray powder pattern: *a* 5.94 Å, *b* 13.56, *c* 7.90, β 90°31′. Assuming $Z = 4$, the calculated specific gravity for $(Co,Mn,Ni)SO_4.4H_2O$ with Co:Mn:Ni = 100:50:50, is 2.359. By suspension in heavy liquids, the measured specific gravity was determined as 2.33.

The name aplowite is proposed for naturally occurring compounds with the ideal formula $CoSO_4.4H_2O$, and is intended to include all the isomorphous tetrahydrate sulphate members in which cobalt is the dominant cation. The mineral is named for A. P. Low (1861–1942), Canadian geologist, and one-time Director of the Geological Survey of Canada.

Aplowite and moorhouseite have been approved as new minerals by the International Commission on New Minerals and Mineral Names.

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