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Lawsonbauerite, a new mineral from the Sterling Hill mine, New Jersey, and new data for torreyite

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Abstract

Lawsonbauerite, $(Mn,Mg)_5Zn_2(SO_4)(OH)_{12} \cdot 4H_2O$, is a new mineral found in the Sterling Hill mine, Ogdensburg, Sussex County, New Jersey. Lawsonbauerite is monoclinic, $P2_1/c$ with $a = 10.54(5)$, $b = 9.62(5)$, $c = 16.46(8)$A, $\beta = 95.21(10)°$, $Z = 4$. The strongest reflections in the X-ray diffraction pattern are (d in A, intensity, *hkl*) 10.5 *100* 100; 5.24 *60* 200; 3.90 *50* $12\bar{2}$; 1.587 *50 hkl?*.

Lawsonbauerite is colorless to white, but most crystals have an amorphous black coating. The Mohs hardness is approximately $4\frac{1}{2}$. The density is 2.87 g/cm^3 (meas), 2.92 g/cm^3 (calc). There is no cleavage and no response to ultraviolet radiation. Optically, lawsonbauerite is biaxial (−) with refractive indices $\alpha = 1.590$, $\beta = 1.608$, $\gamma = 1.611$; $2V_x = 42°$ (meas), 45° (calc). Dispersion is strong, $r > v$. The orientation is Y parallel to b, $c \wedge Z = 7°$ in the acute angle between a and c.

The composition of lawsonbauerite, determined by electron microprobe, is MgO 8.4, MnO 32.6, FeO 0.1, ZnO 23.1, SO_3 10.8 percent, with H_2O 25.0 percent by difference. The ideal formula is $(Mn,Mg)_5Zn_2(SO_4)(OH)_{12} \cdot 4H_2O$. Lawsonbauerite is known only from Sterling Hill and is associated with pyrochroite, zincite, and sussexite.

Lawsonbauerite is the manganese analog of torreyite, which has the ideal composition $(Mg,Mn)_5Zn_2(SO_4)(OH)_{12} \cdot 4H_2O$. New data are given for torreyite, confirming the relationship to lawsonbauerite. Lawsonbauerite is named in honor of Lawson H. Bauer (1889–1954), chief chemist for the New Jersey Zinc Company and describer of torreyite.

Introduction

The new mineral described herein was found in the Sterling Hill mine by a miner, John Kolic, of Rockaway, New Jersey. It was called to the senior author's attention by Mr. Kolic and Mr. Ewald Gerstmann of Franklin, New Jersey. In spite of the mineral's rather insignificant appearance amid a decomposed sussexite–pyrochroite assemblage, they had noticed it by examination with a binocular microscope and recognized it as a mineral new to their experience. This acute observation was a critical component of the discovery of lawsonbauerite, and they are to be commended for their observation and scientific curiosity.

We take pleasure in naming this new mineral lawsonbauerite in honor of the late Lawson H. Bauer (1889–1954), chief chemist of the New Jersey Zinc Company (Frondel, 1955). Lawson Bauer published 18 mineralogical papers, among them the descriptions of nine new minerals, all of which are still valid species. It is particularly appropriate that lawson-

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bauerite is the manganese analog of torreyite, a species first noted by Lawson Bauer and then called *delta-mooreite* (Bauer and Berman, 1929). His analyses have provided a wealth of information about the chemistry of the minerals from Franklin and Sterling Hill, and his thoughtfulness in writing his analyses directly upon the unused portion of the analyzed specimen has ensured the correlation of his analytical data with specific specimens.

Holotype material is preserved in the Smithsonian collection under NMNH catalog #143003. The mineral and the name have been approved by the IMA Commission on New Minerals and Mineral Names.

Physical and optical properties

Lawsonbauerite is colorless to white. The luster of both fresh fracture surfaces and crystal faces is dull to slightly vitreous. There is no cleavage; lawsonbauerite breaks with an even fracture and is moderately brittle. The Mohs hardness is approximately 4½. The density, determined using heavy-liquid techniques, is 2.87(4) g/cm^3, in reasonable agreement with the calculated value of 2.92 g/cm^3. Lawsonbauerite is neither fluorescent nor phosphorescent in ultraviolet radiation.

Optically, lawsonbauerite is biaxial (−) with $2V_x$ = 42(1)° (meas), $2V_x$ = 45° (calc). The refractive indices are α = 1.590(2), β = 1.608(2), and γ = 1.611(2). Dispersion is strong, $r > v$. The orientation is Y parallel to b, $c \wedge Z = 7°$ in the acute angle between a and c. Calculations using the Gladstone–Dale relationship and the constants of Mandarino (1976) yield $K_c = 0.222$ for the chemical analysis and $K_P = 0.210$ for the physical properties, indicating good compatibility (Mandarino, 1979).

Morphology

Crystals of lawsonbauerite on the type specimen are very small (less than 0.5 mm) and are prismatic and bladed in habit. The crystals are elongated on the b axis and flattened parallel to {001}. The forms present are {001} and {100}, in order of decreasing dominance. We observed no twinning, etch figures, or epitaxy with other species. Lawsonbauerite does have a strong tendency to exhibit parallel growth. Lawsonbauerite crystals from another specimen were more complex, but too small for goniometric measurement. They were examined using a scanning electron microscope, and a representative photomicrograph of lawsonbauerite is shown as Figure 1. In this photomicrograph, the crystals are markedly prismatic and are clearly arranged in parallel growth.

X-ray crystallography

Single crystals of lawsonbauerite were examined using precession and Weissenberg methods, which showed that it is monoclinic with lattice parameters a = 10.54(5), b = 9.62(5), c = 16.46(8)A, β = 95.21(10)°, Z = 4. Extinctions are consistent with the space group $P2_1/c$.

X-ray powder diffraction photographs were obtained on a multi-crystal sample mounted in a Gandolfi camera. The data are presented in Table 1, together with new powder diffraction data for torreyite obtained from the type specimen. Although the lattice parameters for lawsonbauerite lead to satisfactory indexing of the powder data, the relatively large values lead to multiple indexing of almost all diffractions. We therefore provide indices for relatively few d values (in Table 1). Except for minor differences in intensities (in part due to imprecision of visual estimations), and the fact that the d values of lawsonbauerite are slightly greater than those of torreyite, the powder data for both species are strikingly similar and are clearly obtained from isostructural phases.

Chemistry

Lawsonbauerite was chemically analyzed with an ARL-SEMQ electron microprobe using an operating voltage of 15 kV and a sample current of 0.15 μA. The data were corrected using a modified version of the MAGIC-4 computer program. The standards used were: synthetic ZnO (Zn), manganite (Mn), barite (S), and hornblende (Fe,Mg). A wavelength-dis-

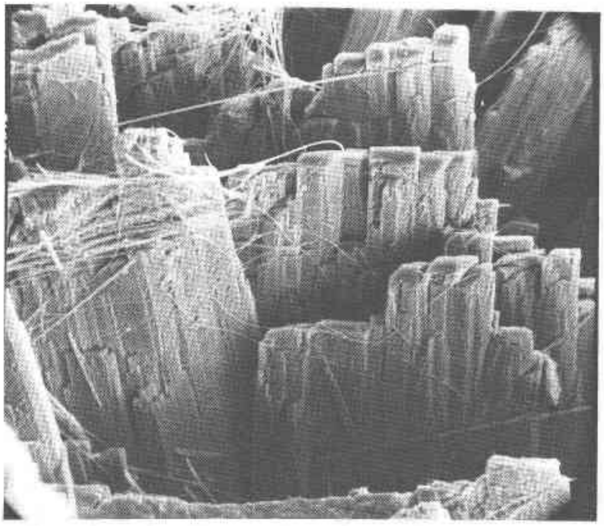

Fig. 1. Scanning electron photomicrograph of lawsonbauerite crystals in parallel growth, associated with filament crystals of sussexite (165×).

Table 1. X-ray powder diffraction data for lawsonbauerite and torreyite

Lawsonbauerite				Torreyite	
I/I_o	d(Obs)	d(Calc)	hkl	I/I_o	d(Obs)
100	10.5	10.5	100	100	10.2
10	8.2	8.3	011	10	8.0
		8.2	002		
5	7.09	7.09	110	5	6.93
30	6.24	6.24	012	30	6.10
60	5.24	5.25	200	50	5.16
20	4.77	4.75	013	10	4.69
20	4.61	4.62	021	20	4.52
		4.61	$20\bar{2}$		
		4.61	210		
10	4.19	4.21	113	5	4.10
		4.19	121		
50	3.90	3.92	$12\bar{2}$	40	3.84
		3.89	212		
20	3.77	3.77	014	10	3.71
10	3.53	3.55	220	20	3.47
		3.51	$22\bar{1}$		
30	3.33			20	3.29
10	3.14			10	3.13
10	2.941			5	2.915
5	2.828			2	2.795
40	2.772			40	2.729
2	2.711			5	2.666
1	2.645			10	2.606
1	2.579			2	2.552
10	2.516			5	2.480
2	2.466				
10	2.402			5	2.376
				2	2.291
1	2.249			5	2.229
1	2.184			1	2.096
2	2.116			1	2.096
1	2.063			1	2.042
				1	1.855
2	1.813			2	1.798
5	1.780			5	1.764
10	1.742			5	1.735
20	1.712			10	1.697
				1	1.622
				5	1.587
50	1.587			50	1.566
				2	1.533
5	1.510			5	1.501
2	1.415			2	1.401
5	1.383				

Powder diffraction data was obtained using a 114.6 mm diameter Gandolfi camera, Si as an internal standard, CuKα X-radiation, Ni filter, visual estimation of intensities and a poly-crystalline sample.

persive microprobe scan indicated the absence of any elements with atomic number greater than nine except those reported herein. A scan by ion microprobe established the absence of any elements with atomic number less than ten, except for abundant hydrogen and oxygen.

The resultant analysis is presented in Table 2, together with Bauer's analysis of torreyite. Water was assigned by difference based on (1) the close crystallochemical relationship between lawsonbauerite and torreyite; (2) the fact that water by difference is very close to the theoretical value; and (3) the presence of significant hydrogen, as indicated by ion microprobe. Although there was insufficient lawsonbauerite for the direct determination of water, there was adequate type torreyite for simultaneous thermogravimetric-evolved gas analysis which yielded 25.9 percent H_2O, confirming Bauer's determination of 26.39 percent, and, by analogy, our assignation of water by difference in lawsonbauerite. The water in torreyite is partially lost under high vacuum (2 percent loss at 25°C for 20 hours) with the remaining 23.9 percent being evolved in six stages between 50 and 505°C.

Semi-quantitative analysis of the type torreyite (Harvard University #113732) confirms the Mn:Mg ratio given by Bauer and the validity of torreyite as a species. Calculation of cation contents for lawsonbauerite, using the cell parameters and the calculated density, yields: $Mn_{13.43}Mg_{6.06}Fe_{0.06}Zn_{8.29}S_{3.92}$, in good agreement with the theoretical composition. The ideal chemical formula of lawsonbauerite is $(Mn,Mg)_5Zn_2(SO_4)(OH)_{12} \cdot 4H_2O$. The fact that zinc approximates to eight atoms per unit cell in both torreyite and lawsonbauerite, and in another semi-quantitative analysis not published here, suggests that zinc likely occupies a unique site, relative to that of magnesium and manganese.

Occurrence and paragenesis

Lawsonbauerite occurs as small, bladed, prismatic crystals intimately intergrown in random arrangement with severely altered fibrous sussexite and pyrochroite. On the type specimen, the crystals are coated with a dull black coating which resembles secondary manganese oxides but yields no diffraction pattern. The coating might have originated from the alteration of lawsonbauerite or the decomposition of the associated pyrochroite. This coating is easily removed by rubbing, thereby exposing the white or colorless lawsonbauerite crystals. Associated species are zincite, calcite, and franklinite. The calcite is intimately mixed with sussexite, and dissolution of the calcite–sussexite admixture leaves a sussexite network similar to that seen on the surface of the specimen. Lawsonbauerite appears to have formed at the same time as sussexite and to have been exposed by the leaching away of the calcite. However, the badly altered nature of the specimen precludes a precise statement on the sequence of formation of these species.

According to Mr. Kolic's careful observations, lawsonbauerite was found in the 1570E stope, about 10 feet below the 1300-foot level of the mine. Several

Table 2. Chemical analyses of lawsonbauerite and torreyite

		MgO	MnO	FeO	ZnO	SO_3	H_2O	Total
Lawsonbauerite	NMNH 143003	8.4	32.6	0.1	23.1	10.8	25.0*	100.00
Theory**		8.25	33.93		22.24	10.94	24.64	100.00
Torreyite	(Bauer analysis)	17.27	17.98		26.30	11.64	26.39	99.58
Torreyite***		17.64	20.69		23.74	11.68	26.25	100.00

* H_2O by difference.

** Theoretical composition for $(Mn_{0.7}Mg_{0.3})Zn_2(SO_4)(OH)_{12}\cdot 4H_2O$.

*** Theoretical composition for $(Mg_{0.6}Mn_{0.4})Zn_2(SO_4)(OH)_{12}\cdot 4H_2O$.

specimens were recovered, but the mineral must be considered very rare. This new species adds one more mineral to the list of 23 species (including kolicite) known to occur only at Franklin or Sterling Hill.

Torreyite

At the outset of our study of lawsonbauerite, the relationship to torreyite was not clear, due in large part to the fact that the powder data for torreyite were in error. Torreyite was originally described by Bauer and Berman (1929), who named it *delta-mooreite* because of its chemical similarity to mooreite. The data of Bauer and Berman have in part been confirmed by the present study, and the rest of their data is assumed to be accurate. Subsequent to their work, *delta-mooreite* was reexamined by Prewitt-Hopkins (1949), and she renamed the phase torreyite. In the same paper she published X-ray data for mooreite, torreyite, and holdenite, all of which were partly in error. The unit cell of mooreite was corrected by Finney (1969). The incorrect powder data for holdenite were corrected by Moore and Araki (1977), and we provide correct data for torreyite in Table 1, thus completing the correction process. Torreyite, $(Mg,Mn)_5Zn_2(SO_4)(OH)_{12}\cdot 4H_2O$, is the magnesium analog of lawsonbauerite, $(Mn,Mg)_5Zn_2(SO_4)(OH)_{12}\cdot 4H_2O$.

Because the physical descriptions of torreyite have been so inadequate for the recognition of this rare species, and because there is little or no physical similarity between the type torreyite and lawsonbauerite, we include a brief description of the mineral.

Torreyite is white to colorless and is only weakly translucent. It breaks with ease into rather equant grains with only a minor degree of brittleness. The luster is dull to vitreous. Twin lamellae are very obvious, resembling those of plagioclase feldspars. Torreyite is characteristically found associated with altered or fresh pyrochroite, sussexite, and zincite. Torreyite in fine-grained aggregates resembles hardened granular sugar. The blue coloration of some specimens is extremely pale and not useful as a diagnostic characteristic. A single crystal of torreyite from the type specimen was investigated using single-crystal methods. Due to the complex mosaic structure of the crystal, all diffractions were so spread out as not to permit an unambiguous determination of unit cell and space group.

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References

Bauer, L. H. and H. Berman (1929) Mooreite, a new mineral, and fluoborite from Sterling Hill, New Jersey. *Am. Mineral., 14,* 165–172.

Finney, J. J. (1969) The unit cell of mooreite. *Am. Mineral., 54,* 973–975.

Frondel, C. (1955) Memorial of Lawson H. Bauer. *Am. Mineral., 40,* 283–285.

Mandarino, J. A. (1976) The Gladstone–Dale relationship—Part I: derivation of new constants. *Can. Mineral., 14,* 498–502.

——— (1979) The Gladstone–Dale relationship. Part III: some general applications. *Can. Mineral., 17,* 71–76.

Moore, P. B. and T. Araki (1977) Holdenite, a novel cubic close-packed structure. *Am. Mineral., 62,* 513–521.

Prewitt-Hopkins, J. (1949) X-ray study of holdenite, mooreite and torreyite. *Am. Mineral., 34,* 589–595.

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