Stringhamite, a new hydrous copper calcium silicate from Utah

JAMES R. HINDMAN

Department of Geology and Geophysics
University of Utah, Salt Lake City, Utah 84112

Abstract

Stringhamite, $CuCaSiO_4 \cdot 2H_2O$, is a new mineral species found in the Bawana mine at the southern end of the Rocky Range, Beaver County, Utah. The mineral occurs as crystals and botryoidal fracture fillings in a diopside-magnetite skarn and is associated with thaumasite, tenorite, kinoite, and calcite.

The space group is $P2_1/c$ with $a_0 = 5.028$, $b_0 = 16.07$, $c_0 = 5.303\text{Å}$, and $\beta = 102.58°$. The five strongest powder diffraction lines are: 8.05 (35), 3.928 (34), 3.236 (39), 2.768 (100), and 2.523 (40).

Crystals are monoclinic and are dominated by {011} and {101}, with {010} and {$\bar{1}$11} also present. The color is azurite blue and the mineral is transparent to translucent. Crystals are biaxial ($+$) with $\alpha = 1.709$ (light grey blue), $\beta = 1.717$ (light blue), and $\gamma = 1.729$ (dark blue); $2V_{calc} = 80°$; $X = b$ and $Y \wedge c = 2.5°$.

The mineral is named in honor of Bronson F. Stringham (1907–1968), late chairman of the Department of Mineralogy at the University of Utah.

Introduction

During examination of specimens of diopside-magnetite skarn collected from the Bawana mine, near Milford, Utah, a mineral resembling azurite was found associated with thaumasite. Further investigation of the mineral indicated that it was a new copper calcium silicate. Though several of the specimens collected in 1969 contained this mineral, it was not until recently that single crystals suitable for space group determination were located at the type locality.

The mineral is named in honor of Bronson F. Stringham (1907–1968), late chairman of the Department of Mineralogy at the University of Utah. (Lovering, 1970). The species and name have been approved by the Commission on New Minerals and Mineral Names, IMA.

Occurrence

Stringhamite is found in a diopside-magnetite skarn formed at the contact of a quartz monzonite with Toroweap limestone (Permian) in the Bawana mine, 4 miles northwest of Milford, Beaver County, Utah. This deposit was originally worked as the Old Hickory mine in the early part of the century and more recently developed into the Bawana open pit. A more complete discussion of the geology and mineralogy of the area may be found in Hintze and Whelan (1973).

Crystals of stringhamite usually occur with crystalline thaumasite on fracture surfaces in the diopside-magnetite skarn. Small radial aggregates of minute crystals also occur with bornite and chalcopyrite disseminated in granular diopside. From examination of the limited number of specimens available, it seems that stringhamite formed by the reaction of copper bearing solutions with diopside. Other minerals associated with stringhamite are tenorite, kinoite, and an undescribed silico-carbonate of copper and calcium.

Although over twenty specimens containing stringhamite have been found, there is probably not more than a gram of the mineral present in the samples, and only a few milligrams were recoverable for study.

Chemistry

The composition of stringhamite is primarily calculated from electron microprobe analyses. Initial qualitative analysis indicated that copper, calcium, and silicon were the only major detectable elements. Quantitative analysis was performed using crystals of shattuckite and dioptase as standards for copper.

Other elements were measured using analyzed pyroxenes, olivines, and feldspars as standards.

Water was determined on a 2 mg sample using thermogravimetric analysis. A weight loss of 12 percent was measured. After heating to 900°C the final decomposition product was identified by X-ray diffraction as a mixture of wollastonite and tenorite.

Initial examination of 100 microprobe data points yielded a formula of $Cu_{.80}Ca_{.91}SiO_{3.8} \cdot 2.11H_2O$. This formula was based on using the difference between the sum of analyzed oxides and 100 percent to obtain a value for water. Magnesium was extremely variable, with MgO ranging from 2.3 percent in massive material to trace amounts in crystal fragments. Consequently, 26 of the initial set of data points having the lowest magnesium content were used for the calculation of copper, calcium, and magnesium. An independent set of 104 data points was used in the determination of iron, aluminum, and silicon. The results of the analyses are presented in Table 1.

Crystal geometry and X-ray diffraction

Weissenburg photographs were taken of a crystal rotated about its a- and b-axes. Systematic extinctions of $(0k0)$, $k = 2n+1$; and $(h0l)$, $l = 2n+1$; were observed indicating a space group of $P2_1/c$. Several crystals were examined to find one suitable for intensity measurements, but all of the crystals examined were multiply twinned. Reflections were made up by as many as 13 closely aligned segments.

A powder pattern was made using a Debye-Scherrer camera which had brass pins placed to cast fiducial marks at 0 and 180 degrees. The pattern was indexed using cell parameters from the Weissenberg photographs, and these parameters were refined with a least squares fit of 19 high angle lines. The cell parameters thus obtained for stringhamite are: $a_0 = 5.028$ (5), $b_0 = 16.07$ (2), $c_0 = 5.303$ (6) Å, and $\beta = 102.58°$ (9). The calculated cell volume is 418.20Å³. The X-ray powder pattern is presented in Table 2.

Physical and optical properties

Stringhamite is deep azurite blue in color, with fragments being transparent to translucent. Crystals are biaxial (+) with $\alpha = 1.709$, $\beta = 1.717$, and $\gamma = 1.729$ for sodium light; $2V_{calc} = 80°$, $X=b$, $Y \wedge c = 2.5°$. The mineral is pleochroic with α = light grey blue, β = light blue, γ = dark blue.

The infrared spectrum was obtained from a potassium bromide disc containing stringhamite which had

TABLE 1. Electron microprobe chemical analysis of stringhamite

	S-1	S-2	S-3	$CuCaSiO_4 \cdot H_2O$
CuO	31.63 (.22)*	33.41 (.82)	34.10 (.89)	34.32
CaO	24.64 (.28)	25.40 (.58)	26.97 (.80)	24.20
MgO	.54 (.12)	.01 (.04)	.94 (.97)	
FeO	.23 (.04)	.77 (.35)	N.D.	
Al_2O_3	.03 (.04)	.07 (.13)	.07 (.06)	
SiO_2	28.42 (2.11)	26.95 (5.48)	27.46 (.67)	25.93
H_2O**	14.52	13.39	10.46	15.55
H_2O***		12.		

S-1 Stringhamite; botryoidal incrustation.
S-2 Stringhamite; crystal fragments.
S-3 Mineral F, Crestmore Quarry, California.
* Standard deviations are given in parenthesis.
** H_2O determined by difference.
*** H_2O determined by thermogravimetric analysis.

been hand picked for purity. The spectra is shown in Figure 2. The presence of (H_2O) was verified by peaks at 3150 and 2890, cm⁻¹, while the other peaks are indicative of SiO_4^{-4}.

The density of stringhamite was measured on 100–200 mesh grains which had first been concentrated magnetically. Due to similarities in both density and magnetic properties, pure samples of stringhamite could only be obtained by hand sorting from a concentrate of approximately 20 percent stringhamite and 80 percent diopside. Repeated measurements of densities of stringhamite-diopside suspensions in methylene iodide indicates that the density of stringhamite spans a range of 3.16 to 3.18 gm/cm³ at 20°C. This measured density is appreciably less than the density of 3.67 calculated from X-ray data. Because of this discrepancy, all the material used for thermogravimetric, infrared, and density determinations was verified by X-ray diffraction before the determinations were made.

The density and measured refractive indices were deciding factors in choosing a final formula of $CuCaSiO_4 \cdot 2H_2O$. If the TGA value for water of 12 percent is used in calculating the chemical formula, a formula of $Cu_2Ca_2Si_2O_8 \cdot 3H_2O$ would be obtained. A

TABLE 2. X-ray data for stringhamite*

d_{obs}	I/I_0	(h k l)	d_{calc}	d_{obs}	I/I_0	(h k l)	d_{calc}
8.049	35	020	8.035	2.003	11	080	2.009
4.884	21	100	4.907	1.964	20	132	1.961
4.687	20	110	4.693	1.875	17	081	1.873
4.370	9	021	4.351	1.806	11	260	1.809
4.182	20	120	4.188	1.756	7	152	1.762
3.928	34	1̄11	3.905	1.729	8	251	1.729
3.618	21	1̄30	3.618	1.657	11	162	1.656
3.236	39	1̄31	3.218	1.614	23	202	1.614
2.768	100	131	2.764	1.595	14	3̄31	1.592
2.690	10	150	2.689	1.551	19	2̄81	1.549
2.609	19	002	2.588	1.530	5	271	1.530
2.523	40	141	2.516	1.482	19	3̄32	1.482
2.481	14	022	2.463	1.429	14	143	1.427
2.431	18	210	2.425	1.385	1	262	1.382
2.344	18	220	2.347	1.347	1	291	1.347
2.222	16	2̄31	2.214	1.334	1	351	1.337
2.089	15	112	2.090	1.310	1	083	1.309
2.031	11	211	2.034	1.276	1	024	1.277

* Pattern made with 114 mm Debye-Scherrer camera using Cu K-alpha radiation. Intensities measured with photodensitometer.
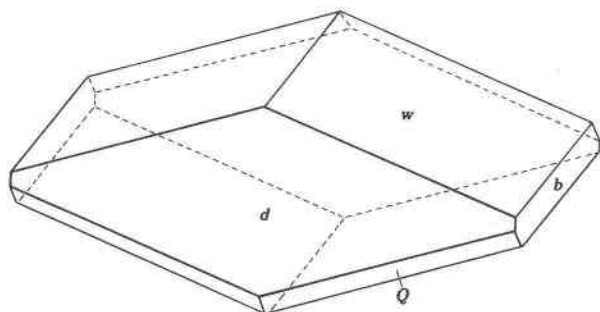
FIG. 1. Typical habit of a stringhamite crystal. $d = (101)$; $w = (011)$; $b = (010)$; $Q = (\bar{1}11)$.

TABLE 3. Comparison of stringhamite and Mineral F

Stringhamite			Mineral F*		
d	I/I_0	hkl	d	I/I_0	hkl
8.049	35	020	8.013	32	020
4.884	21	100	4.928	20	100
4.687	20	110	4.691	18	110
4.370	9	021	4.363	14	021
4.182	20	120	4.220	5	120
3.928	34	$\bar{1}11$	3.951	31	$\bar{1}11$
3.618	21	130	3.611	23	130
3.236	39	$\bar{1}31$	3.242	56	$\bar{1}31$
2.768	100	131	2.770	100	131
2.344	18	220	2.355	22	220
2.003	11	080	1.996	16	080
1.875	17	081	1.876	36	081
1.806	11	260	1.811	12	260
1.729	8	251	1.713	10	251
1.614	23	202	1.602	62	202
1.551	19	$\bar{2}81$	1.555	22	$\bar{2}81$
1.530	5	271	1.521	18	271
1.429	14	143	1.437	20	143
1.347	1	291	1.338	16	291

* Lines coinciding with those of calcite are omitted.

mean refractive index was calculated for both formulas, using specific refractive energies listed in Larsen and Berman (1934) and Mrose (1965). Using a density of 3.18, the calculated n's are 1.701 and 1.685 respectively. The measured β of 1.717 for stringhamite is in good agreement with the first value of 1.701.

Several crystals of stringhamite were examined by scanning electron microscopy. One of the larger crystals had a core of angular crystal fragments. The resulting voids might account for the low measured density. Because all of the reflections examined on single crystal photographs were composed of multiple twin segments, it is assumed that this twinning is present in all of the stringhamite studied.

Crystal morphology

Individual crystals are rare. Crystal habit is strongly monoclinic with (011) and (101) being the dominate forms and (010) and ($\bar{1}11$) present to a minor extent. This typical habit is shown in Figure 1. Size does not exceed 0.1mm for crystals thus far observed.

Relationship to "Mineral F"

In 1943 A. O. Woodford assigned the designation "Mineral F" to a mineral occurring as crystalline blue films coating joint planes in rock at Crestmore Quarry, Riverside County, California (Woodford, 1943, p. 362). A specimen of Mineral F was examined by X-ray diffraction. The specimen consisted of blue films on coarsely crystalline calcite. The powder pattern obtained is compared to the Bawana material in Table 3. An electron microprobe examination of Mineral F also yielded results essentially identical to those of stringhamite.
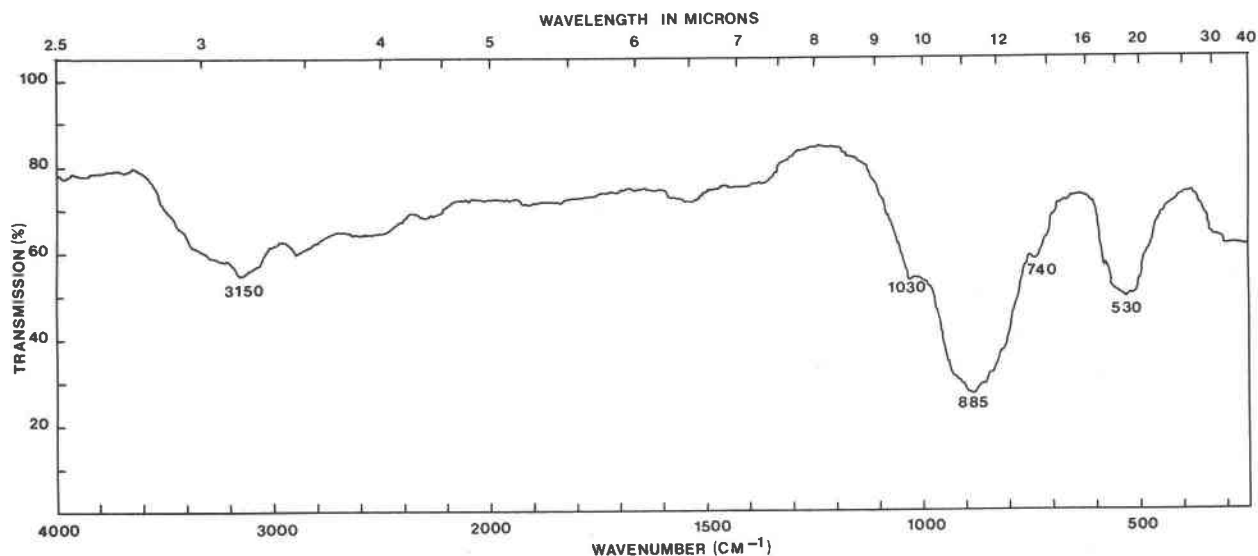

FIG. 2. Infrared absorption spectra of stringhamite.

Stringhamite from Christmas Mine, Arizona

Additional information on stringhamite from another locality was obtained too late for adequate discussion. Sidney A. Williams, working independently on material from the Christmas Mine, measured the following cell parameters: $a_0 = 10.04$, $b_0 = 16.12$, $c_0 = 5.34$ Å, and $\beta = 102.91°$. The stringhamite from Arizona does not contain measurable magnesium and has a unit cell double that of the type material. This is indicated in the powder pattern by a line of 3.037 Å which is not present in powder patterns of the Bawana stringhamite.

Acknowledgments

References

HINTZE, LEHI F., AND JAMES A. WHELAN (1973) Geology of the Milford area. *Utah Geol. Assoc. Publ. 3.*

LARSEN, ESPER S., AND HARRY BERMAN (1934) The microscopic determination of the nonopaque minerals, 2nd Ed. *U.S. Geol. Surv. Bull.* **848.**

LOVERING, T. S. (1970) Memorial of Bronson F. Stringham. *Am. Mineral.,* **55,** 607–614.

MROSE, MARY E. (1965) New specific refractive energy values for CuO and Sc₂O₃. *Am. Mineral.,* **50,** 288.

WOODFORD, A. O. (1943) Crestmore minerals. *Calif. Div. Mines Rep.* **39,** 333–365.