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A RESTUDY OF MAGNOLITE, $Hg_2^{1+}Te^{4+}O_3$, FROM COLORADO[1]

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Abstract

Museum specimens of magnolite, ideally $Hg_2^{1+}Te^{4+}O_3$, from the type locality, Keystone mine, Boulder County, Colorado, and from the Mt.Lion mine, in the same county, are orthorhombic, *Pbm*2, *a* 5.948(4), *b* 10.580(9), *c* 3.745(2) Å, *V* 235.7(5) Å^3, *a*:*b*:*c* 0.5622:1:0.3540. With $Z = 2$, the calculated density is 8.12 g/cm^3 for the theoretical formula. The strongest seven lines of the X-ray powder pattern [*d* in Å(*I*)(*hkl*)] are: 5.26(50)(020,110), 3.95(70)(120), 3.74(40)(001), 3.043(100)(021,111,130), 2.587(50)(220), 1.986(40)(150,300) and 1.757(50)(060,151,301,241). The average of five electron microprobe analyses is Hg_2O 72.3(6), TeO_2 28.9(5), total 101.2 wt.%. With O = 3, the empirical formula is $Hg^{1+}_{1.94}Te^{4+}_{1.01}O_3$. Magnolite from the Keystone mine occurs both as mm-sized radiating tufts of needles and as isolated masses of parallel to subparallel bladed crystals in cracks and cavities of the quartz-bearing host rock. Associated minerals are native mercury, massive quartz, black sooty coloradoite, yellow spongy native gold, and acicular tufts of dark green to brownish orange keystoneite. Individual needles are elongate [001], creamy white and opaque, silky and soft. They do not exceed 0.5 mm in length and have an approximate length-to-width ratio of 100:1. Bladed crystals, up to 1 mm in length, are elongate [001] with striations parallel to [001] on {100}. The blades are colorless, have an adamantine lustre, are brittle, transparent to translucent, and possess a perfect cleavage parallel to the striations and a good cleavage normal to them. Forms observed are {100} major and {010} minor. Crystals from Mt.Lion are light yellow-green. The mineral is nonfluorescent in ultraviolet light, and the streak is light brown. Magnolite is biaxial positive; all indices of refraction exceed 2; 2*V*(meas) ≥45°; indicatrix orientation: *X* = *b*, *Y* = *a* and *Z* = *c*. There is no observable dispersion or pleochroism.

Keywords: magnolite, Keystone mine, Mt. Lion mine, electron-microprobe analyses, X-ray data, mercurous tellurite, Boulder County, Colorado.

Sommaire

Des spécimens de magnolite, de formule idéale $Hg_2^{1+}Te^{4+}O_3$, provenant de la localité type, la mine de Keystone, dans le comté de Boulder, au Colorado, ainsi que la mine de Mt. Lion, dans le même comté, repérés de musées, sont orthorhombiques, *Pbm*2, *a* 5.948(4), *b* 10.580(9), *c* 3.745(2) Å, *V* 235.7(5) Å^3, *a*:*b*:*c* 0.5622:1:0.3540. Avec *Z* = 2, la densité calculée est de 8.12 pour la formule citée. Les huit raies les plus intenses du cliché de poudre [*d* en Å(I)(*hkl*)] sont: 5.26(50)(020,110), 3.95(70)(120), 3.74(40)(001), 3.043(100)(021,111,130), 2.587(50)(220), 1.986(40)(150,300) et 1.757(50)(060,151,301,241). La moyenne de cinq analyses à la microsonde électronique donne Hg_2O 72.3(6), TeO_2 28.9(5), total 101.2% (en poids). En supposant trois atomes d'oxygène, la formule empirique est $Hg^{1+}_{1.94}Te^{4+}_{1.01}O_3$. La magnolite de Keystone se présente à la fois sous forme de touffes fibro-radiées et de masses isolées de prismes aplatis parallèles à sub-parallèles dans les fissures et les cavités de la roche hôte quartzifère. Lui sont associés: mercure natif, quartz massif, coloradoïte noire fuligineuse, or natif spongieux, et keystoneïte en touffes de cristaux aciculaires vert sombre à orange brunâtre. Les cristaux aciculaires de magnolite sont allongés sur [001], blanc crème opaque, soyeux et tendres. Leur longueur ne dépasse pas 0.5 mm; le rapport de longueur à largeur est approximativement de 100 à 1. Les prismes aplatis peuvent atteindre 1 mm de longueur; ils sont allongés sur [001] et montrent des stries parallèles à [001] sur {100}. Ils ont un éclat adamantin, et sont cassants, incolores et transparents à translucides; ils possèdent un clivage parfait parallèle aux stries et un bon clivage perpendiculaire à celles-ci. Nous avons observé les formes {100} (dominante) et {010} (secondaire). Les cristaux provenant de Mt. Lion sont gris-jaune clair. La magnolite n'est pas fluorescente en lumière ultraviolette, et sa rayure est brun clair. Elle est biaxe positive, et tous les indices de réfraction sont supérieurs à 2. L'angle 2*V* (mesuré) est égal ou supérieur à 45°, et l'orientation de l'indicatrice est: *X* = *b*, *Y* = *a*, *Z* = *c*. Nous n'avons décelé ni dispersion, ni pléochroïsme.

Mots-clés: magnolite, mine de Keystone, mine de Mt. Lion, analyses à la microsonde électronique, données de diffraction X, tellurite mercureux, comté de Boulder, Colorado.

Introduction

Magnolite was originally described by Genth (1877) from the Keystone mine, Boulder County, Colorado as a new "mercurous tellurate", with the probable formula Hg_2TeO_4. The name recalls the

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Magnolia mining district, in which the Keystone deposit occurs. Genth found the mineral to occur as fine white bundles or tufts of silky white needles, some radiating, and to have formed as the result of the oxidation of coloradoite. Magnolite was found sparingly, associated with native mercury, quartz, limonite and psilomelane, in the upper oxidized part of the mine. These data were abstracted by Dana (1892) for his Sixth Edition (p. 980). Inexplicably, the mineral data and name were deleted from the Seventh Edition, edited by Palache *et al.* (1951). Moreover the name has never appeared as a valid mineral species in any edition of Fleischer's Glossary of Mineral Species (*e.g.*, Fleischer 1987). Although both Hey (1950) and Strunz (1970) abstracted the name and formula for their mineralogical compilations, most mineralogists justifiably have regarded magnolite as, at best, a doubtful species, as neither a new occurrence nor additional mineralogical data have been reported for over one hundred years.

In 1978 one of the authors (W.W.P.) purchased a portion of the Lazard Cahn mineral collection. Cahn, a serious mineral collector, resided in Colorado Springs and thus was particularly interested in mineral species found in Colorado. One of the newly acquired specimens was labeled "magnolite with coloradoite, Keystone mine, Magnolia mining district, Colorado". A megascopic examination revealed some white fibers consistent with the physical description for magnolite originally reported by Genth (1877). X-ray powder diffraction by the first author, a few years later, produced a set of powder data that did not fit any known mineral or inorganic phase listed with the ICDD/JCPDS Powder Diffraction File. Further study of the specimen revealed colorless crystals, coated with a thin film of native mercury, that gave a powder pattern identical to that produced by the fibers. In places these crystals surround globules of native mercury. A more detailed mineralogical study of magnolite was initiated, and the resultant data are reported herein.

Approximately five to six magnolite-bearing specimens are known to exist in North American mineral collections. Most of these specimens are in the F.A. Genth collection, housed at the Pennsylvania State University, University Park, Pennsylvania. One piece forms part of the collection at the Pinch Mineralogical Museum, Rochester, New York. A portion of the examined specimen has been deposited in the Systematic Reference Series of the National Mineral Collection, Geological Survey of Canada, Ottawa (NMC 65534).

Three specimens from the Keystone mine and one from the Mt. Lion mine (also located in Boulder County) were studied megascopically and by X-ray powder diffraction. All contain visible amounts of magnolite, but in small quantities. The mineral must be considered rare; the total amount of detectable magnolite does not exceed 10 mg. Associated minerals identified on the specimens are native mercury, massive quartz, yellow spongy gold, black sooty coloradoite, and dark green to brownish orange acicular aggregates of keystoneite (Back *et al.* 1988). Keystoneite most likely is identical to "ferrotellurite" (Genth 1877). Further details regarding the mineralogy and geology of the Magnolia mining district can be found in Vanderwilt (1947).

Physical and Optical Properties

On the museum specimens, labeled to have originated from the Keystone mine, magnolite occurs as mm-sized radiating tufts of acicular needles on fracture surfaces, and as isolated masses of parallel to subparallel bladed crystals, typically coated with a thin veneer of native mercury, in cracks and cavities of the quartz-bearing host rock. Individual needles are creamy white and elongate [001], do not exceed 0.5 mm in length, and have an approximate length-to-width ratio of 100:1. They are soft and opaque, and possess a silky luster. These physical characteristics are identical to those reported by Genth (1877). Individual crystals, up to 1 mm in length, are elongate [001], with striations parallel to [001] on {100}, colorless with an adamantine luster, brittle, and transparent to translucent; they possess a perfect cleavage parallel to the striations and a good cleavage normal to them. Forms observed are {100} major and {010} minor. These crystals are too small for an accurate determination of hardness, but they are definitely harder than the associated needles. Crystals from the Mt. Lion mine specimen are physically identical to the crystals from the Keystone mine except that the color is light yellow-green. All magnolite grains are nonfluorescent under both long- and short-wave ultraviolet light. Lightly crushed crystals are distinctly zoned from a dark brown core, to medium brown, to a pale yellow edge. Crushed grains possess a light brown streak. There was insufficient pure uncoated material available for a determination of density using the Berman balance.

Optical measurements of magnolite crystals were made on a spindle stage using the white light. The mineral is biaxial positive with all indices of refraction greater than 2. The measured $2V$ is equal to, or greater than, 45°. Optical orientation is $X = b$, $Y = a$ and $Z = c$. Neither dispersion nor pleochroism was observed. The calculated mean index of refraction $\bar{n}$, assuming theoretical $Hg_2^{1+}Te^{4+}O_3$ and a calculated density of 8.12 g/cm^3, is 2.30 when a Gladstone–Dale constant k of 0.144 is assumed for Hg_2O. The mean index of refraction is 2.24 when a k of 0.134 for Hg_2O is assumed (Mandarino 1978).

TABLE 1. X-RAY POWDER DATA FOR MAGNOLITE

Iest	*dmeas*	*dcalc*	*hkl*	*Iest*	*dmeas*	*dcalc*	*hkl*
50	5.25	5.29	020	5	2.030	2.031	141
		5.18	110	40	1.986	1.994	150
70	3.95	3.95	120			1.983	300
40	3.74	3.75	001	35	1.944	1.943	231
30	3.170	3.169	101	10	1.875	1.873	002
		3.057	021	3	1.856	1.857	320
100	3.043	3.036	111			1.763	060
		3.034	130	50	1.757	1.760	151
3	2.976	2.974	200			1.752	301
20	2.864	2.863	210			1.748	241
3	2.637	2.645	040	10	1.723	1.724	250
50	2.587	2.592	220	5	1.691	1.692	122
30	2.356	2.357	131	10	1.665	1.663	321
20	2.327	2.329	201	10	1.593	1.593	132
5	2.276	2.274	230	10	1.567	1.569	331
3	2.132	2.132	221			1.566	251

114.6 mm Debye – Scherrer powder camera, Cu radiation
Ni filter ($\lambda CuK\alpha$ 1.54178 Å); indexed with *a* 5.948, *b* 10.580, *c* 3.745 Å

X-Ray Studies

Two crystal fragments of magnolite were examined by single-crystal precession methods employing Zr-filtered Mo radiation. One was mounted such that *b**, and the other such that *c**, is parallel to the dial axis. The following levels were collected: *0kl*, *1kl*, *h0l*→ *h2l*, *hk*0 and *hk*1. Precession films indicate orthorhombic symmetry, with measured unit-cell parameters *a* 5.94, *b* 10.54 and *c* 3.743 Å. Systematic absences, *0kl* with $k \neq 2n$, dictate diffraction aspect *Pb***. The permissible space-groups therefore are *Pbmm* (51), $Pb2_1m$ (26) and *Pbm*2 (28). The last choice is the correct space-group, as determined from crystal-structure studies (Grice 1989). The refined unit-cell parameters, *a* 5.948(4), *b* 10.580(9), *c* 3.745(2)Å, *V* 235.7(5)Å^3 and $a{:}b{:}c$ = 0.5622:1:0.3540, are based on 15 X-ray powder lines between 3.74 and 1.567 Å for which unambiguous indexing was possible. A fully indexed powder pattern is presented in Table 1. All indexed reflections were checked on single-crystal precession films. With $Z = 2$, the calculated density for theoretical $Hg_2^{1+}Te^{4+}O_3$ is 8.12 g/cm^3.

Chemistry

Magnolite crystals from the Keystone mine were analyzed with a Cameca CAMEBAX electron microprobe utilizing an operating voltage of 20 kV, a 31.4 nA beam current and a 10 µm beam spot. Natural coloradoite (HgTe) was used as a standard. The average of 5 analyses gave Hg_2O 72.3(6), TeO_2 28.9(5), total 101.2 wt.%. Assuming O = 3, the empirical formula for the mercurous tellurite is $Hg_{1.94}^{1+}Te_{1.01}^{4+}O_3$. The ideal formula, $Hg_2^{1+}Te^{4+}O_3$, requires Hg_2O 72.33, TeO_2 27.67, total 100.00 wt.%. The valence states for both mercury and tellurium, as well as the number of oxygen atoms, were determined by crystal-structure analysis (Grice 1989) prior to interpretation of the electron-microprobe results.

This formula is remarkably close to that originally proposed by Genth (1877), the major difference being the absence of one oxygen atom. Genth correctly determined that tellurium is tetravalent, but assumed that mercury is divalent; thus, the extra oxygen atom in his formula was necessary for charge balance. Nevertheless, it was an excellent achievement considering the state of the science more than one hundred years ago.

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