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SONORAITE

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ABSTRACT

The new mineral sonoraite, $Fe_2^{3+}Te_2^{4+}O_5(OH)_4 \cdot H_2O$, was found at the Moctezuma tellurium-gold mine in Sonora, Mexico. It resembles emmonsite, with which it is associated, but has higher luster and a different habit. There are 4 formula units per cell: $a=10.984\pm0.002$, $b=10.268\pm0.001$, $c=7.917\pm0.002$ Å, $\beta=108.49\pm0.02°$, $P2_1/c$, $D(\text{calc})=4.179$, $D(\text{obs})=3.95\pm0.01$ gm/cm³. It is biaxial negative, $\alpha=2.018$, $\beta=2.023$, $\gamma=2.025$, all ±0.003. $2V$ ranges from 20° to 25°.

INTRODUCTION

In 1962, in the course of a study of minerals from the oxidized zone of the Moctezuma tellurium-gold mine (Gaines, 1965), three hand specimens were noted of a yellowish-green crystallized mineral which occurs associated with emmonsite but differs from it in crystal habit and luster. Subsequent investigation showed that this mineral is a new iron tellurite, for which the name "sonoraite" has been approved by the Commission on New Minerals and Mineral Names of the I.M.A.

OCCURRENCE

The first specimen found was one on which sharp white cavernous anglesite crystals 0.5 to 1.5 mm across were implanted upon hair-like, curved crystals of emmonsite thickly coating a cavity in limonite-stained quartz. Intimately associated with the emmonsite at the bottom of the cavity was a group of blade-like single crystals and sheaves of sonoraite 0.5 to 1.0 mm across. Subsequently, another specimen was found in which sheaves of subparallel crystals of sonoraite were implanted on limonite-covered quartz; emmonsite in rosettes and curved rods appeared elsewhere on the specimen. In the last example encountered there were several rosettes of dark yellowish-green sonoraite implanted on limonite. On some of the sonoraite rosettes there was a later growth of hair-like emmonsite crystals. The total amount of material found amounted to probably less than 20 mg, a fact that seriously hampered and delayed this investigation.

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CHEMICAL COMPOSITION (Max H. Hey)

Sonoraite is readily soluble in dilute hydrochloric acid. Upon heating, it loses water and turns brown. X-ray fluorescence analysis shows only iron and tellurium to be present as cations.

A portion of 889.2 μg was weighed out on an Oertling decimicro balance and dissolved in 5.6 ml cold concentrated HCl in a weighed 10-ml beaker (solution was complete after standing overnight), and the solution was divided by weight approximately equally between four 10-ml measuring flasks. Sulphosalicylic acid (1 ml of 20%) and excess ammonia were added to two of the flasks, and iron was determined colorimetrically at λ 425 mμ against a standard that had been checked gravimetrically. In the other two portions of solution, tellurium was determined colorimetrically at 400 mμ against a standard prepared from the element, using the purple sol obtained by stannous chloride reduction and stabilized by gum arabic (Johnson, 1958); the amount of acid used to dissolve the mineral initially was calculated to give the correct strength for this determination.

It had been intended to determine water by difference, but as the Fe_2O_3 plus TeO_2 amounted to only 80 percent, it was felt desirable to check the water by loss on gentle ignition and to look for insoluble impurities (none had been seen when the 889-μg portion was dissolved, but on this scale small amounts of insolubles readily escape notice).

A fragment of sonoraite (225.0 μg) was weighed into a small capsule of platinum foil, 9 mm in diameter, 1.5 mm deep, and weighing 93.2 mg (though the maximum difference between the loads on the two pans of the decimicro balance is only 1.3 mg, the maximum load on each pan is 250 mg). The capsule was placed inside a small porcelain crucible, covered, and heated in a muffle furnace for 1 hour at 500°C; the loss in weight was 41.0 μg, and the sonoraite fragment had cracked and turned a deep red-brown, but had not fused. In a blank check, the platinum capsule lost no weight.

The dehydrated mineral was dissolved in two drops of concentrated HCl in the cold; after standing overnight solution appeared to be complete, and the solution was diluted with a drop of water and filtered. This operation was effected by dropping a small piece of Whatman 42 filter paper into the solution, pressing it firmly against the bottom of the capsule with the tip of a 5-ml pipette held in a clamp, and applying gentle suction by mouth, through a rubber tube attached to the pipette. The paper and capsule were washed repeatedly with drops of a mixture of 2.8 ml concentrated HCl and 3 ml water, applied by means of a small dropper. The paper was burnt off in the muffle and the tiny residue of insolubles weighed; it proved to be less than 1 μg in weight.

The filtrate in the pipette was washed into a weighed 20-ml beaker with the remainder of the acid wash-liquid and divided about equally between two 10-ml measuring flasks; check determinations of Fe and Te were made on these two solutions.

The results are shown in Table 1 together with the analytical and theoretical data for emmonsite, which was analyzed to obtain a check on the procedure used for sonoraite. The water (or more accurately, ignition loss, presumed to be water) is the weakest point in the analysis. As will be shown below, crystallographic evidence shows sonoraite to be a monohydrate, with 4 OH groups per formula unit.[1]

CRYSTALLOGRAPHY

Crystals of sonoraite are monoclinic holohedral (2/*m*), thin platy in habit, yellowish-green in color, transparent, and much more lustrous

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[1] Note added in proof: A recent reevaluation of the Pauling bond strengths distribution in the crystal structure suggests the formula $Fe_2^{3+}Te_2^{4+}O_6(OH)_2 \cdot 2H_2O$, so that we are dealing with a dihydroxy dihydrate rather than a tetrahydroxy monohydrate.

TABLE 1. ANALYSES AND THEORETICAL COMPOSITIONS OF SONORAITE AND EMMONSITE

	1	2	3	4	5
Fe_2O_3	27.9	23.8	23.67	29.97	30.8
TeO_2	52.5	73.1	70.99	59.89	58.0
H_2O	18.2	[3.1]	5.34	10.14	[10.1]
	98.6	[100.0]	100.00	100.00	[99.9]

1. Sonoraite, Moctezuma mine, Moctezuma, Sonora, Mexico. Fe_2O_3 is the mean of 27.3 and 28.5; TeO_2, of 51.8 and 53.2 (M. H. Hey, analyst).
2. Emmonsite, Moctezuma mine, Moctezuma, Sonora, Mexico; water by difference. Analysis on 892 μg (M. H. Hey, analyst).
3. Theoretical composition of $Fe_2Te_3O_9 \cdot 2H_2O$, emmonsite.
4. Theoretical composition of $Fe_2Te_2O_5(OH)_4 \cdot H_2O$, sonoraite.
5. Sonoraite calculation of column 1, recalculated to give 10.1 wt % water.

than emmonsite crystals. Their habit shows little variation. With reference to the cell given below, the dominant form is the pinacoid {100}. Striations are parallel to *c* on {100} and on the rhombic prism {110}, the faces of which bevel the plates. The only other observed form is another rhombic prism, {011}. The three observed forms are those predicted by the Generalized Law of Bravais (Donnay and Harker, 1937) for space group $P2_1/c$, which is indeed found to be the correct space group from X-ray diffraction and confirms the holohedry.

The cell dimensions were determined from zero and upper-level precession and Weissenberg films obtained with crystals mounted with *a* or *b* along the axis of the goniometer head. Crystals commonly occur in sheaves and rosettes forming subparallel and radiating aggregates; to find single crystals, a careful selection between crossed nicols must be made. Their softness ($H \sim 3$) makes them physically difficult to handle. Back-reflection Weissenberg films taken at 21°C with CuKα radiation ($\lambda\alpha_1 = 1.54051$, $\lambda\alpha_2 = 1.54434$ Å) about *a* and *b* axes lead to the following cell dimensions after data refinement with C. W. Burnham's LCLSQ least-squares program: $a = 10.984 \pm 0.002$, $b = 10.268 \pm 0.001$, $c = 7.917 \pm 0.002$ Å, $\beta = 108.49 \pm 0.02°$, $V = 846.8 \pm 0.5$ Å^3, space group $P2_1/c$.

The density was determined on a single grain weighing about 1.0 mg by adjusting the density of a Clerici solution containing the grain until it remained suspended. No wetting problem was experienced. A density of 3.95 ± 0.01 g/cm^3 was obtained. A structure determination (Donnay, Stewart, and Zemann, 1968) shows the formula unit to be $Fe_2^{3+}Te_2^{4+}O_5(OH)_4 \cdot H_2O$, which leads to $D_{calc} = 4.179$ g/cm^3 for $Z = 4$.[1]

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[1] See footnote on p. 1829.

TABLE 2. X-RAY POWDER DATA OF SONORAITE

hkl	*d* (calc.), Å	*d* (obs.), Å	*I* (vis. est.)	*hkl*	*d* (calc.), Å	*d* (obs.), Å	*I* (vis. est.)
100	10.417	10.40	10	$\bar{1}22$	3.133	3.110	8
110	7.313	7.36	3	031	3.114		
011	6.061	6.09	4	$\bar{1}31$	3.098		
$\bar{1}11$	5.941	—	—	$\bar{3}02$	3.083	—	—
200	5.209	—	—	112	3.073	3.035	5
020	5.134	5.18	5	221	3.032		
111	4.738	—	—	022	3.030	—	—
210	4.645	4.66	8	$\bar{2}22$	2.971	2.974	4
120	4.605	—	—	$\bar{3}21$	2.958	—	—
$\bar{2}11$	4.571	—	—	$\bar{3}12$	2.952	—	—
021	4.238	4.24	1	131	2.882	—	—
$\bar{1}21$	4.197	—	—	320	2.876	2.867	2
$\bar{1}02$	3.954	—	—	230	2.860		
002	3.754	—	—	$\bar{2}31$	2.843	—	—
121	3.701	—	—	122	2.728	—	—
$\bar{1}12$	3.690	—	—	311	2.727	2.722	2
220	3.656	3.66	6	202	2.670		
$\bar{2}02$	3.642			$\bar{4}11$	2.652	—	—
$\bar{2}21$	3.620	—	—	$\bar{3}22$	2.643	2.642	2
211	3.529	3.53	3	400	2.604	—	—
012	3.526			$\bar{1}32$	2.588	—	—
300	3.472	—	—	212	2.584	2.584	2
$\bar{2}12$	3.433	3.41	3	040	2.567	—	—
$\bar{3}11$	3.413			$\bar{4}02$	2.552	—	—
310	3.289	3.290	7	$\bar{1}13$	2.548	—	—
130	3.252			231	2.530	—	—
102	3.221	—	—	032	2.529	—	—
				410	2.524	2.524	2
				$\bar{2}13$	2.521		

Sonoraite is biaxial negative, with $\alpha = 2.018$, $\beta = 2.023$, and $\gamma = 2.025$; all values are accurate to ±0.003, determined with Cargille oils. $2V$ is in the range 20° to 25°. No pleochroism was observed. Spacings from a powder pattern, taken with FeKα radiation ($\lambda = 1.9373$ Å), are compared with calculated spacings (Table 2) based on the above cell dimensions. Whenever possible, single-crystal intensities were used to help with the indexing of lines that could be ascribed to more than one reflection.

NAME

The name sonoraite is proposed for this mineral in reference to Sonora, the state in the Republic of Mexico in which the Moctezuma mine is located.

TYPE MATERIAL

One of the three specimens of sonoraite has been deposited at the U. S. National Museum, specimen No. 119271.

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