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Yeatmanite: new data

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Abstract

Type specimens of yeatmanite are re-examined and X-ray powder-diffraction data are presented for yeatmanite. Least-squares refinement of the powder data yield unit-cell parameters of $a = 5.604(2)$, $b = 11.602(7)$, $c = 9.058(4)$A, $\alpha = 92°10(3)'$, $\beta = 100°54(2)'$, $\gamma = 77°18(5)'$. Microprobe analyses confirm the chemical formula of yeatmanite as $[Mn_5Sb_2][Mn_2Zn_8Si_4]O_{28}$, instead of the originally proposed formula of $(Mn,Zn)_{16}Si_4Sb_2O_{29}$. Yeatmanite remains a species unique to Franklin, New Jersey.

Introduction

Yeatmanite was originally described by Palache *et al.* (1938) from Franklin, Sussex County, New Jersey. It is a very rare manganese zinc antimonate silicate which is known only from the Franklin mineral deposit. Its crystal structure was discussed by Moore (1966) and Moore *et al.* (1976) who showed that it is closely related to katoptrite (catoptrite) and is probably a stuffed pyrochroite-type structure.

The original yeatmanite specimen (HU#92878) was found intimately associated with pink sarkinite, $Mn_2(AsO_4)(OH)$, and light green willemite, Zn_2SiO_4, in the Franklin mine. The dark brown easily-cleaved yeatmanite occurs as euhedral crystals and laths imbedded in both sarkinite and willemite, but only where they are in mutual contact. In this assemblage, yeatmanite is likely the first phase to have formed.

A second paragenesis was found in 1944 by John Baum, then resident geologist (now retired) for the New Jersey Zinc Company, but a description has never been published. According to Baum, the second occurrence was found in a small lenticular body located at 830S, 170E, elevation −760 in the 730S Palmer shaft pillar, in the third sub-level below 750 level. On either side of this lenticular body was franklinite–willemite ore containing limy bands. The sample was taken 52 feet from the hanging wall contact and 54 feet from the footwall contact.

In this paragenesis, yeatmanite occurs as euhedral crystals in a fine-grained massive matrix. Thin-section examination indicates that other minerals are present in small amounts, among them diopside and andradite (both containing about 8.5% MnO) and romeite (containing small amounts of lead, zinc, iron, and manganese in addition to calcium and antimony). The sequence of formation appears to be diopside, followed by andradite and romeite, followed by yeatmanite. Only the yeatmanite is euhedral; the others occur as formless blebs and rounded grains.

Few specimens of yeatmanite are known, and some have possibly been overlooked in the past due to the lack of X-ray diffraction data. The paucity of specimens requires some comment on their locations. Only one specimen is known from the second occurrence described by Baum. It was sliced in three pieces, one of which remains in the Baum collection, the others repose in the Harvard University collection (HU#116461), and the Smithsonian collection (NMNH#144444). Of the original yeatmanite, associated with sarkinite, type specimens have been preserved at Harvard University (HU#92878), the Smithsonian Institution (NMNH#C6290), and the Academy of Natural Sciences of Philadelphia (ANSP#22631).

Subsequent to the completion of this study, a third

Table 1. Unit-cell parameters for yeatmanite

	Palache et al. (1938)	Present Study
a	5.52(1) A	5.604(2) A
b	11.56(1) A	11.602(7) A
c	9.029(10) A	9.058(4) A
α	$92(1)^{\circ}48'$	$92^{\circ}10(3)'$
β	$101(1)^{\circ}45'$	$100^{\circ}54(2)'$
γ	$76(1)^{\circ}11'$	$77^{\circ}18(5)'$
V	548.18 A^3	564.21 A^3
Z	1	1

paragenesis for yeatmanite was discovered. This occurrence, originally labeled bannisterite, consists of a 1.0cm vein of willemite and calcite in massive franklinite. The yeatmanite occurs as warped foliae admixed with the willemite and calcite.

Physical and optical properties

The density of yeatmanite was given by Palache *et al.* (1938) as 5.02 g/cm³. We determined the density, with a Berman balance, to be 4.91 g/cm³. Inasmuch as the value obtained by Palache is in excellent agreement with the value of 5.04 g/cm³ for the formula proposed by Moore *et al.*, (1976), our value may be low due to air or liquid trapped along incipient cleavages.

Indices of refraction and other optical data for yeatmanite were determined on sample #C6290 (analysis #1) with the spindle-stage designed by Jones (1968) and white light. The refractive indices of the oils were determined with a Leitz Jelley refractometer. The refractive indices are $\alpha = 1.864(4)$, $\beta = 1.895(4)$ and $\gamma = 1.905(2)$. These are lower than the values reported by Palache *et al.* (1938), who gave $\alpha = 1.873$, $\beta = 1.905$, and $\gamma = 1.910$. $2V$ was measured as 52° by direct rotation between the optic axes of a properly oriented grain; the calculated value is 59°. Dispersion is distinct, $r > v$, X is perpendicular to the {100} cleavage. Yeatmanite is not fluorescent in ultraviolet radiation.

Application of the Gladstone–Dale relationship with the constants of Mandarino (1976) yields, for the chemical analyses of this study, values of K_C which vary from 0.177 to 0.179 with a mean of 0.178. These compare extremely well with the value 0.178 for K_P obtained from our refractive indices and the calculated density of 5.04 g/cm³.

X-ray powder-diffraction data

X-ray powder-diffraction data are not available for yeatmanite, and this has likely been a factor contributing to the small number of specimens identified to date. The diffraction pattern of a type specimen (#C6290) used for analysis #1, Table 3, was recorded using a 114.6mm diameter Gandolfi powder camera. The diffraction maxima were indexed by the computer program of Appleman and Evans (1973). The unit-cell dimensions of Palache *et al.* (1938) were used as starting parameters. The refined unit-cell parameters are given in Table 1 and the powder-diffraction data in Table 2. The X-ray powder-diffraction patterns of all yeatmanite specimens examined are nearly identical, with no measurable change in cell dimensions with slight variations in the Mn:Zn ratio.

Chemistry

Two analyses of yeatmanite were given by Palache *et al.* (1938). They proposed the formula $(Mn,Zn)_{16}Si_4Sb_2O_{29}$, noting that manganese and zinc

Table 2. X-ray powder diffraction data for yeatmanite

hkl	d (calc.)	d (obs.)	I/Io	hkl	d (calc.)	d (obs.)	I/Io
001	8.894	9.0	5	250	1.953		
020	5.660	5.66	5	$1\bar{3}0$	1.946	1.945	30
110	5.321	5.32	5	$\bar{2}23$	1.942		
$\bar{1}\bar{1}1$	4.983	4.94	5	$\bar{2}\bar{1}4$	1.915	1.916	40
002	4.447	4.44	10	160	1.915		
111	4.240	4.24	1	$\bar{3}\bar{1}2$	1.818	1.818	1
022	3.504	3.51	5	$\bar{1}44$	1.815		
$\bar{1}12$	3.441	3.435	5b	$0\bar{5}3$	1.796	1.796	1
$\bar{1}21$	3.433			015	1.758	1.757	1
003	2.965	2.969	100	$0\bar{1}5$	1.756		
$\bar{1}22$	2.951			252	1.707	1.708	1
$\bar{2}11$	2.781	2.782	60			1.671	30
210	2.751	2.753	30			1.656	30
132	2.590	2.587	60			1.621	30
$\bar{2}\bar{1}2$	2.567	2.547	40			1.605	60
$\bar{2}\bar{3}1$	2.474	2.474	60			1.583	40
$\bar{1}41$	2.279	2.276	1			1.569	30
$1\bar{3}2$	2.277					1.489	30
$\bar{2}\bar{1}3$	2.239	2.237	1			1.431	5
$\bar{2}22$	2.144	2.146	40			1.415	40
$1\bar{2}3$	2.143					1.377	3b
						1.370	3b

Pattern obtained with polycrystalline sample in 114.6 mm diameter Gandolfi camera using CuKα nickel-filtered X-radiation with NBS silicon as an internal standard. Intensities estimated visually.

Table 3. Microprobe and prior analyses of yeatmanite

	Microprobe analyses				In Palache et al.(1938)			
Sample #	C6290	R9371	22621	144444	Bauer #1	Bauer #2	Theory**	Theory***
SiO_2	14.7	14.6	14.4	14.5	13.59	14.31	14.13	14.05
Sb_2O_5	18.9	18.5	18.6	18.9	18.12	18.68	19.02	18.90
MnO	37.8	33.2	33.0	33.8	33.21	37.45	33.37	29.02
ZnO	29.1	35.1	34.7	31.5	34.72	28.65	33.48	38.03
FeO	1.0	tr.	tr.	tr.	0.36	0.91	0.00	0.00
MgO	0.0	0.0	tr.	1.6	n.g.	n.g.	0.00	0.00
Total	101.5	101.4	100.7	100.3	100.00	100.00	100.00	100.00
	Cations per unit cell****							
Si	4.08	4.05	4.01	4.03	3.77	3.97		
Sb	1.95	1.91	1.92	1.95	1.87	1.93		
Mn	8.89	7.81	7.83	7.95	7.81	8.80		
Zn	5.97	7.20	7.11	6.46	7.12	5.87		
Fe	0.23	0.00	0.00	0.00	0.08	0.21		
Mg	0.00	0.00	0.00	0.66	n.g.	n.g.		
$\Sigma\ \underline{M}^{2+}$	15.09	15.01	14.94	15.07	15.01	14.88		

* - Academy of Natural Sciences of Philadelphia (Part of Harvard University # 92878).

** - Theoretical composition for yeatmanite with Mn:Zn = 8:7. n.g. = not given

*** - Theoretical composition for yeatmanite with Mn:Zn = 7:8. tr. = trace

**** - Calculated from refined unit-cell parameters and observed density of 4.91 g/cm^3.

C6290, R9321 and 144444 are from the Smithsonian collection. Accuracy of data: ± 3% of the amount given.

were present in approximately equal amounts. Moore *et al.* (1976) proposed the formula $[Mn_5Sb_2][Mn_2Zn_8Si_4]O_{28}$ to demonstrate the close relationship to katoptrite, $[Mn_5Sb_2][Mn_8Al_4Si_2]O_{28}$.

Four specimens of yeatmanite were chemically analyzed on an ARL-SEMQ electron microprobe with an operating current of 15 kV and a sample current of 0.15μA. The standards used were valentinite for Sb, manganite for Mn, synthetic ZnO for Zn, and hornblende for Si, Fe, and Mg. Duplicate analyses with other standards have confirmed the results given herein. The data were corrected using a modified version of the MAGIC-4 computer program. The results are presented in Table 3, together with the analyses of Bauer from Palache *et al.* (1938). The data show that the composition of yeatmanite varies only slightly from sample to sample; the main variation is in the Mn:Zn ratio. It would seem that Palache *et al.* (1938) relied more heavily upon Bauer's analysis #1 in computing the chemical formula of yeatmanite; however, the analyses of this study confirm the higher silica content of Bauer's analysis #2. Specimen #C6290 is from the Bauer collection; its composition is very similar to Bauer's analysis #2, suggesting it is the same sample, and if so, confirming his analytical results.

The new analyses confirm the formula of yeatmanite proposed by Moore *et al.* (1976) and, by extension, the analogy to katoptrite. We note that the analytical data supports a Mn:Zn ratio of 8:7 instead of the 7:8 ratio in the proposed formula. This is likely, as Moore *et al.* (1976) noted, by "assuming limited solution of Mn^{2+} for Zn^{2+} in tetrahedral positions." Any ambiguity in the number of Mn and Zn atoms will likely be resolved by future structural studies of yeatmanite.

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