

## Veatchite-A, a new modification of veatchite

IŞIK KUMBASAR

*I.T.U. Maden Fakültesi  
Maçka-Istanbul, Turkey*

### Abstract

A third modification of veatchite occurs in Emet colemanite deposit, Kütahya, Turkey, as white cauliflower-shaped nodules associated with colemanite, hydroboracite, realgar, orpiment and montmorillonite. The new mineral is triclinic, space group  $A1$  or  $A\bar{1}$ ;  $a = 20.80$ ,  $b = 11.72$ ,  $c = 6.63\text{Å}$  (all  $\pm 0.3$  percent),  $\alpha = 90^\circ$ ,  $\beta = 90^\circ 48'$ ,  $\gamma = 91^\circ 57'$  (all  $\pm 05'$ );  $a:b:c = 1.774:1:0.565$ ; cell volume  $1615\text{Å}^3$ ;  $Z = 4$ . Density (meas) 2.73, (calc) 2.77 g/cm<sup>3</sup>. The strongest lines in the X-ray powder photograph and their estimated intensities are: 10.40,100; 3.32,70; 2.59,50; 2.84,20; 3.45,15.

Crystals are transparent, colorless, and well developed and show plate form with rhombic shape. Common forms are {100}, {011}, and {01 $\bar{1}$ }. Twin lamellae are parallel to {100}. Cleavage {100} perfect and parallel to dominant plate form, {011} and {01 $\bar{1}$ } good; (011) $\Delta$ (01 $\bar{1}$ )  $\sim 60^\circ$ . Optically biaxial (+),  $\alpha = 1.549$ ,  $\beta = 1.551$  (calc),  $\gamma = 1.621 \pm 0.002$  (Na light),  $2V = 25^\circ \pm 1^\circ$ ;  $Z = b$ ,  $X = c$ ;  $r < v$  strong.

The chemical analysis is (weight percent): SrO 30.88, CaO 0.25, MgO 0.04, B<sub>2</sub>O<sub>3</sub> 58.15, H<sub>2</sub>O(+) 9.63, H<sub>2</sub>O(-) 0.15 (total 99.2).

DTA analysis shows endothermic peaks at 455°, 630°, 940°C. Two different phases form at 455° and 630°C.

The new modification is named veatchite-A according to the recommended nomenclature system of polytypes.

### Introduction

Veatchite-A was collected from Killik (Emet Borax Company) and Hisarcık (Etibank) colemanite mines in Emet, Kütahya, Turkey. Crystal habit, optical properties, chemical composition, and X-ray powder pattern are similar to those found for veatchite and p-veatchite within the limits of observational errors. Only single-crystal studies show that the mineral has a different space group and crystal class. It is named veatchite-A in order to correspond to the recommended nomenclature system of polytypes (Bailey, 1977). The name has been approved by the IMA Commission on New Minerals and New Mineral Names.

The type material ( $\sim 2$ kg) is deposited in Istanbul Technical University Mining Faculty.

### Occurrence

The Emet borate deposits have been formed in the sediments of playa lakes during the Neogene according to Özpeker (1969), and during the Middle Oligo-

cene according to Helvacı and Firman (1976). Borate formations are interbedded with clays, marls and volcanic tuffs, and are related to volcanic activity.

The principal mineral of Emet borate deposits is colemanite. In Killik mine, it is associated with hydroboracite, ulexite, veatchite-A, tunellite (Helvacı and Firman, 1976), meyerhofferite (Helvacı and Firman, 1976), cahnite (Helvacı and Firman, 1976), realgar, orpiment, calcite, and aragonite; in Hisarcık area with hydroboracite, ulexite, terruggite, cahnite (Helvacı and Firman, 1976), veatchite-A, celestite, gypsum, native sulphur, realgar, orpiment, and calcite.

Veatchite-A occurs in cauliflower-shaped nodules (Fig. 1) ranging from 0.5 to 10cm in diameter. Nodules are rarely composed of countless minute euhedral crystals, but are commonly compact with euhedral crystals on the surface forming radiating aggregates. Realgar, orpiment, and montmorillonite occur among the crystals and in small veinlets. The nodules are found in clays, on colemanite nodules,

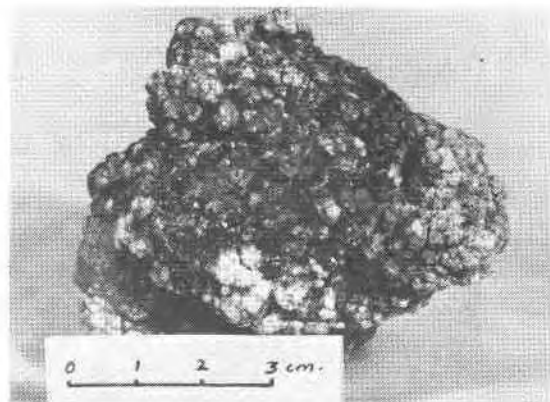


Fig. 1. Veatchite-A nodule showing characteristic cauliflower shape.

and on hydroboracite occurrences. Replacement of colemanite by veatchite-A is seen in thin sections and also on the macroscopical samples. The formation of veatchite-A is later than hydroboracite and colemanite where hydroboracite is an alteration product of colemanite. Veatchite-A is not associated with tunelite.

#### Physical and optical properties

Crystals are platy on {100}. Most common forms are {100}, {011} and {01 $\bar{1}$ }; (011) $\wedge$ (01 $\bar{1}$ ) $\sim$ 60°. The length of the crystals varies up to 2mm. The general length-to-thickness ratio is about 10:1 (Fig. 2).

Under the polarizing microscope, polysynthetic twin lamellae parallel to {100} are seen. Twinning was also observed on an  $hk0$  precession photograph of one of the crystals. For veatchite and p-veatchite twinning has not been reported.

The mineral is colorless, with pearly luster on perfect cleavage faces. Optical properties are summarized in Table 1. Pale pink and green polarization colors are seen on sections parallel to {100}, the optic plane.

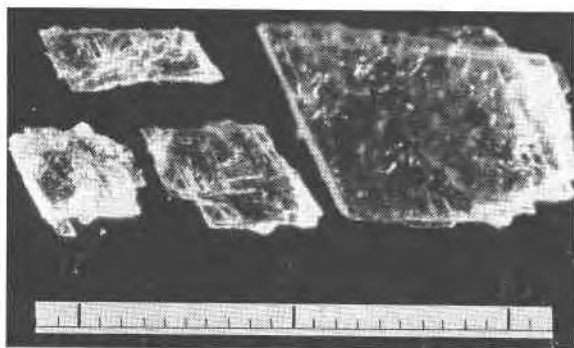


Fig. 2. Crystals of veatchite-A (1 division = 0.1mm).

Table 1. Optical properties of veatchite, p-veatchite and veatchite-A

	Veatchite* California USA	P-veatchite** Reyershausen Germany	Veatchite-A*** Kütahya Turkey
Optic plane (Na light)	(100)	(010)	(100)
$\alpha$	1.550 $\pm$ 0.002	1.550 $\pm$ 0.002	1.549 $\pm$ 0.002
$\beta$	1.553(calc.)	1.553 $\pm$ 0.002	1.551(calc.)
$\gamma$	1.621 $\pm$ 0.002	1.621 $\pm$ 0.002	1.621 $\pm$ 0.002
$\gamma-\alpha$	0.071 $\pm$ 0.004		0.072 $\pm$ 0.004
Optic sign	positive	positive	positive
2V	25 $\pm$ 2°	25° (calc.)	25 $\pm$ 1°
Optical orientation	Z//b X//c Y $\wedge$ a = -2°	Z $\wedge$ a = 29°40' X//c Y//b	Z//b X//c
Dispersion			strong r < v

\*The indices of refraction and 2V are from Kramer and Allen (1956) and optical orientation is from Clark and Mrose (1960).

\*\*The indices of refraction and 2V are from O. Braitsch (1959) and optical orientation is from Clark and Mrose (1960).

\*\*\*Present study.

Calculated density obtained with the Gladstone and Dale relationship is 2.77 $\pm$ 0.05 g/cm<sup>3</sup>. This agrees with the calculated density, 2.77 g/cm<sup>3</sup>, obtained by using the unit-cell dimensions and chemical formula. The specific gravity measured by suspension in bromoform-acetone at 23°C is 2.73 $\pm$ 0.02. Veatchite-A crystals are platy and generally composed of stacked cleavage plates, probably containing entrapped air. Larger crystals (about 1 mm) float on the liquid surface, presumably held there by surface tension.

#### X-ray data

Unit-cell dimensions were determined using precession photographs (Cu radiation, Ni filter) with  $a$ ,  $b$ , and  $c$  as precession axes for zero-level photographs and with  $a$  as precession axis for first- and second-level photographs. The crystals were colorless, transparent, platy with rhombic shape: a representative one was 0.5  $\times$  0.3  $\times$  0.006 mm in size. The short reciprocal axis is normal to the dominant plate form, as in veatchite and p-veatchite. Unit-cell dimensions are similar to those of veatchite, but the angles differ slightly and the intensities of equivalent reflections are not compatible with monoclinic symmetry. Systematic extinctions indicate the space group  $A1$  or  $A\bar{1}$ . There are reflections only for  $hkl$ ,  $k + l = 2n$ . The conditions for  $h0l$ ,  $h = 2n$  ( $l = 2n$ ) and  $0k0$ ,  $k = 2n$  do not exist. The resulting data are given in Table 2. The dimensions of the primitive unit cell obtained by transforming the A-centered unit cell with the matrix 100/0  $\frac{1}{2}$  -  $\frac{1}{2}$ /001 are:  $a = 20.80$ ,  $b = 6.73$ ,  $c = 6.63\text{Å}$ ,  $\alpha = 119^\circ 27'$ ,  $\beta = 90^\circ 48'$ ,  $\gamma = 91^\circ 17'$  (space group  $P1$  or  $P\bar{1}$ ).

Table 2. Crystallographic data for veatchite-A and veatchite

	Veatchite-A (Kütahya) Present study	Veatchite (California) Clark and Christ (1971)
Symmetry	Triclinic	Monoclinic
Space group	A1 or A1	Aa
a (Å)	20.80	20.860±0.005
b	11.72 (all±0.3%)	11.738±0.003
c	6.63	6.652±0.002
α	90°00'	(90°)
β	90°48' (all±05')	92.10°±0.03
γ	91°57'	(90°)
Volume (Å <sup>3</sup> )	1615	1627.67±0.005
Cell content	4[4SrO.11B <sub>2</sub> O <sub>3</sub> .7H <sub>2</sub> O]	4[4SrO.11B <sub>2</sub> O <sub>3</sub> .7H <sub>2</sub> O]
Density		
g/cm <sup>3</sup> , calc.	2.77	2.664
meas.	2.73±0.02	2.66

\* Cell dimensions were measured from precession photographs and corrected for film shrinkage.

X-ray powder patterns were taken with a 114.59mm diameter powder camera using Ni-filtered Cu radiation, and the measurements were corrected for film shrinkage. Observed and calculated  $d(hkl)$  and intensities of the observed powder lines are listed in Table 3. The powder pattern of veatchite-A is similar to those of veatchite and p-veatchite.

Table 3. X-ray powder diffraction data for veatchite-A\*

Calculated		Observed		Calculated		Observed	
hkℓ	d <sub>hkℓ</sub> (Å)	d <sub>hkℓ</sub> (Å)	I	hkℓ	d <sub>hkℓ</sub> (Å)	d <sub>hkℓ</sub> (Å)	I
200	10.39	10.40	vs	720	2.613		
				711	2.610		
120	5.688	5.63	w	502	2.610		
111	5.602			800	2.598	2.592	vs
120	5.588			440	2.589		
111	5.565			531	2.587		
111	5.552			422	2.517		
220	5.178			440	2.515	2.502	vw
211	5.108	5.11	w	422	2.492		
211	5.053			631	2.441		
500	4.157	4.09	m	540	2.433		
		3.63	w	602	2.412	2.42	vw
				820	2.406		
600	3.464			522	2.403		
520	3.446	3.45	s			2.350	w
511	3.420					2.191	m
131	3.341					2.077	m
520	3.337					2.047	m
131	3.332					1.924	m
511	3.328	3.32	vs			1.838	m
002	3.315					1.794	m
131	3.309					1.752	m
131	3.303					1.6543	w
						1.5901	w
231	3.168	3.12	w			1.5395	w
202	3.145						
122	2.859						
122	2.855						
431	2.853						
122	2.847	2.84	s				
240	2.844						

\* Indices and  $d(\text{calc.})$  from the least-squares analysis of x-ray powder data using a computer program N.Kumbasar, (I.T.U.).

Table 4. Chemical analysis of veatchite-A (weight percent)

	Original	Recalculated to 100
SrO	30.88	31.22
CaO	0.25	0.25
MgO	0.04	
B <sub>2</sub> O <sub>3</sub>	58.15	58.79
H <sub>2</sub> O(+)	9.63	9.74
H <sub>2</sub> O(-)	0.15	Σ 100.00
Ba	0.0024	
Al	0.035	
Fe	0.015	
Mn	0.0069	
Cu	-	
Total	99.197	

### Chemical composition

About 2g of euhedral crystals were selected under a binocular microscope for chemical analysis. Wet-chemical analyses were carried out by Dr. K. Inan, Technical University of Istanbul. Ca, Mg, and trace elements were determined by the atomic absorption technique. The results are given in Table 4.

Chemical composition of veatchite-A is similar to those of veatchite and p-veatchite (Table 5), and is compatible with the chemical formula (4SrO·11B<sub>2</sub>O<sub>3</sub>·7H<sub>2</sub>O) found by structural analysis of veatchite (Clark and Christ, 1971; Rumanova *et al.*, 1971).

Veatchite-A is not soluble or only slightly soluble in hot water (80°C).

### Differential thermal analysis

A differential thermal analysis of veatchite-A was made in air at one atmosphere from room temper-

Table 5. Chemical data for veatchite, p-veatchite and veatchite-A (weight percent)

	Veatchite Lang, California USA		P-veatchite U.S.S.R.	Veatchite-A Turkey	Calculated com.
	1	2	3	4	5
SrO	30.0	30.72	32.4	31.22	31.73
CaO	1.6	1.69	-	0.25	-
B <sub>2</sub> O <sub>3</sub>	58.5	57.96	58.0	58.79	58.62
H <sub>2</sub> O	9.6	9.63	9.6	9.74	9.65
	99.7	100.00	100.0	100.00	100.00

- 1) Switzer and Brannock (1950)
- 2) Kramer and Allen (1956)
- 3) Kondrat'eva (1964)
- 4) Present study
- 5) for 4SrO.11B<sub>2</sub>O<sub>3</sub>.7H<sub>2</sub>O.

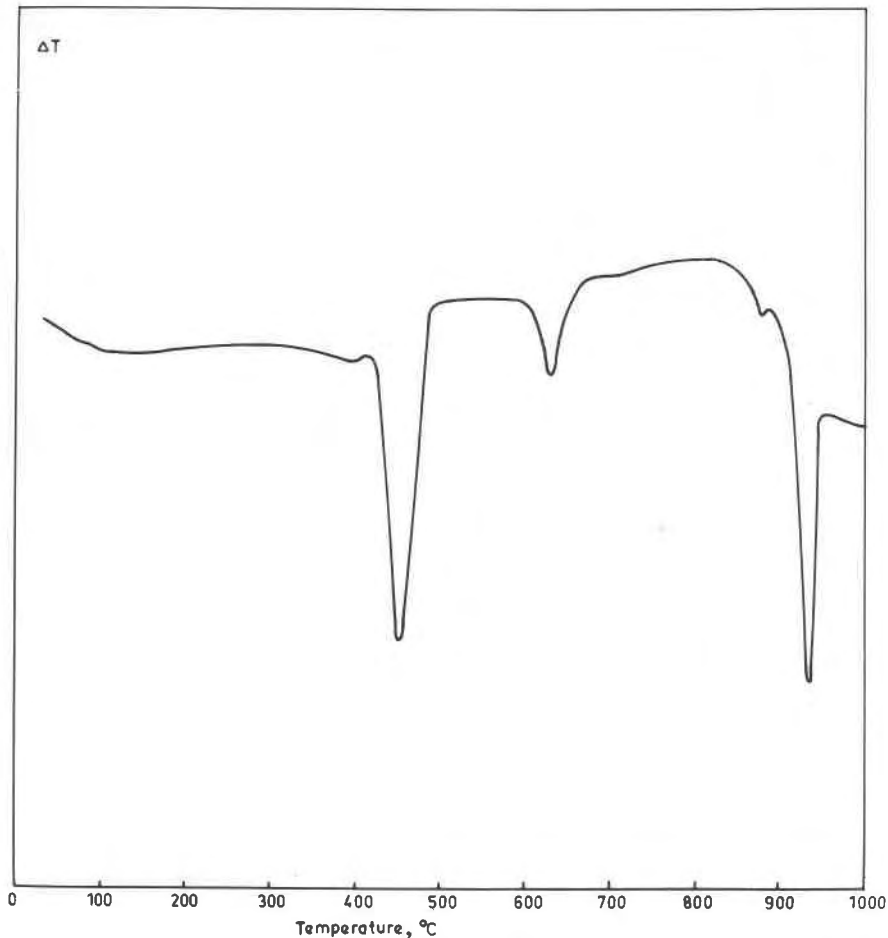


Fig. 3. DTA curve for veatchite-A. Rate of heating  $10^{\circ}\text{C}/\text{min}$ ; thermocouple Pt/Pt+Rh; reference material :  $\text{Al}_2\text{O}_3$ .

ature to  $1000^{\circ}\text{C}$ . The resulting pattern is shown in Figure 3.

Endothermic reaction starts immediately because of adsorbed water. There are large endothermic peaks at  $455^{\circ}$ ,  $630^{\circ}$ ,  $940^{\circ}$  and small endothermic peaks at  $300^{\circ}$ ,  $360^{\circ}$  and  $880^{\circ}\text{C}$ . A small exothermic peak is seen at  $660^{\circ}$ , and an exothermic reaction beginning at  $710^{\circ}$  continues slightly till  $840^{\circ}$ . The thermogravimetric curve shows loss of weight at  $100^{\circ}$ ,  $400^{\circ}$ ,  $450^{\circ}$ , and  $630^{\circ}\text{C}$ . The amount of weight loss at each step found from the thermogravimetric curve is about 0.83 percent at  $100^{\circ}$ , 7.10 percent at  $400^{\circ}$ – $450^{\circ}$  and 1.91 percent at  $630^{\circ}\text{C}$ .

The mineral was heated at  $50^{\circ}$ ,  $100^{\circ}$ ,  $200^{\circ}$ ,  $400^{\circ}$ ,  $500^{\circ}$ ,  $700^{\circ}$ ,  $800^{\circ}$ , and  $900^{\circ}\text{C}$  and diffractometer runs were made on the resulting products. There are no distinct differences on the patterns of the products for  $50^{\circ}$ ,  $100^{\circ}$ ,  $200^{\circ}$ , and  $400^{\circ}\text{C}$  and they are similar to those of veatchite-A. The products of  $500^{\circ}$  and

$700^{\circ}\text{C}$  give different patterns. The  $d$  values and relative intensities (in parentheses) are: for the phase formed at  $630^{\circ}\text{C}$ : 10.84(20), 7.28(10), 5.48(20), 3.65(100), 3.34(25), 2.887(10), 2.738(90), 2.187(50); for the phase formed at  $455^{\circ}\text{C}$ : 10.06(90), 8.82(70), 4.37(40), 3.46(70), 3.31(100), 3.20(25), 3.02(30), 2.91(40), 2.858(40), 2.603(60), 2.508(35), 2.442(35), 2.113(40).

Microscopic examination of these products shows that the euhedral shape of the crystals is not lost. The products after  $455^{\circ}\text{C}$  are biaxial with negative sign and show low birefringence.

#### Acknowledgment

I thank Dr. Joan R. Clark, U.S. Geological Survey, for her generous and continuous comments and encouragement during the course of the study and for her kindly review of the manuscript. The work has been carried out at the laboratories of the Mining Faculty, Technical University of Istanbul, Turkey.

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*Manuscript received, April 13, 1978;  
accepted for publication, October 5, 1978.*