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PABSTITE,[1] THE TIN ANALOGUE OF BENITOITE

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ABSTRACT

Pabstite is a new barium tin titanium silicate found in recrystallized siliceous limestone from a quarry at Santa Cruz, California. The mineral occurs in small fractures and as scattered grains in association with quartz, calcite, tremolite, witherite, phlogopite, diopside, forsterite and taramellite. The tin-bearing minerals cassiterite, franckeite and stannite are present locally. Pabstite is found as small anhedral, colorless to white grains with a pink tinge on a fresh surface, and appears rarely in crystal form showing a trigonal outline. The mineral fluoresces bluish white in short-wave ultraviolet light.

Pabstite is uniaxial (−) and has abnormal interference colors. Refractive indices are $\omega=1.685$, $\epsilon=1.674$. The measured specific gravity is 4.03 g/cm^3, and calculated density is 4.07 g/cm^3. Single-crystal investigations confirm the presence of the symmetry elements of space group $P\bar{6}c2$, the same as that of benitoite. The dimensions of the unit cell are $a=6.706\pm0.002$, $c=9.829\pm0.002$ Å. Its composition, determined by electron-probe microanalysis, is $Ba(Sn_{0.77}Ti_{0.23})Si_3O_9$.

The mineral is named for Professor A. Pabst of the Department of Geology and Geophysics, University of California, Berkeley.

INTRODUCTION AND ACKNOWLEDGMENTS

Pabstite, the barium tin titanium silicate, was discovered in 1963 by Gail Dunning and Joseph Cooper, mineral collectors, at the Pacific Limestone Products Quarry in Santa Cruz, California. Pabstite-bearing material was submitted to the California Division of Mines and Geology for identification. *X*-ray powder photographs of the mineral were very similar to those of benitoite, with only slight changes in line spacings. A qualitative examination by emission-spectrographic procedures showed the presence of considerable tin, which could account for the refractive indices that are lower than those for benitoite.

The authors gratefully acknowledge the cooperation of Messrs. Dunning and Cooper who generously supplied most of the material studied. The criticisms and suggestions of various members of the California Division of Mines and Geology are also appreciated. The microprobe analysis was made possible through funds provided by the National Science Foundation.

The mineral was named for Dr. A. Pabst, Professor of Mineralogy at the University of California, Berkeley; his contributions to mineralogy in general, and specifically to that of California, are widely known. The

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[1] Name approved by the IMA Commission on New Minerals and Mineral Names.

name, pabstite, is designated for those compositions in which Sn predominates over Ti.

OCCURRENCE

To date pabstite has been found only at the Santa Cruz locality; however, a benitoite containing a small amount of tin has been recovered from a drill core of recrystallized limestone taken at Rush Creek in eastern Fresno County, California. It is conceivable that pabstite may also be found at this locality. At Santa Cruz, pabstite occurs both as fracture filling and as disseminated grains in recrystallized siliceous limestone which shows evidence of contact metamorphism. It is associated with calcite, quartz, tremolite, witherite, phlogopite, diopside, minor amounts of forsterite and taramellite. The tin-bearing sulfosalts, stannite and franckeite, and cassiterite are dispersed throughout the host limestone, although only in minor amounts.

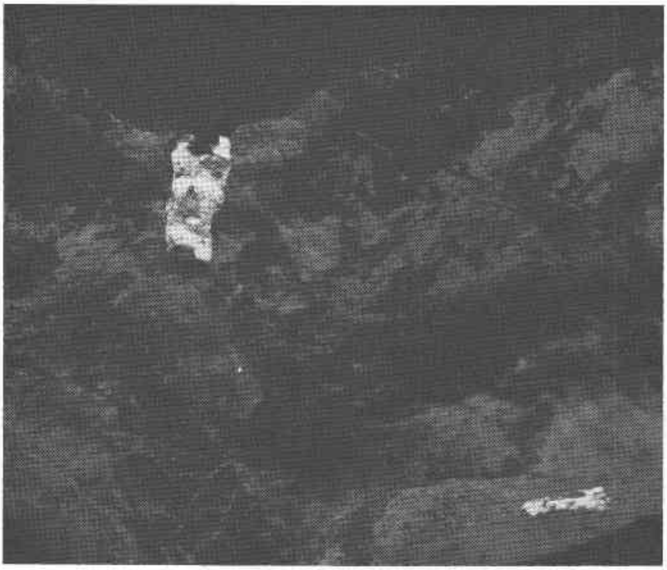

FIG. 1. Pabstite (white) associated with taramellite (black) and quartz (gray) taken under short-wave ultraviolet light. ×1.5. Photo by Dunning.

PHYSICAL AND OPTICAL PROPERTIES

Pabstite usually occurs as anhedral grains that are colorless to white, with a pink tinge when freshly broken. Most specimens were recognized in the field by fluorescence under ultraviolet light. Grains are commonly

TABLE 1. PHYSICAL AND OPTICAL PROPERTIES OF PABSTITE AND BENITOITE

	Pabstite	Benitoite
Composition	$Ba(Sn_{0.77}Ti_{0.23})Si_3O_9$	$BaTiSi_3O_9$
Crystal system	Hexagonal	Hexagonal
Optic sign	Uniaxial (−)	Uniaxial (+)
Refractive indices	$\omega=1.685$	$\omega=1.757$[1]
	$\epsilon=1.674$	$\epsilon=1.804$[1]
Hardness	6	6

[1] Louderback, 1909.

less than 2 mm in diameter and aggregates do not exceed 10 mm (Fig. 1). After acid etching of the enclosing carbonate rock, a few crystals were found with a trigonal outline. The grains are vitreous and usually include small rods of tremolite which make a clean separation of the mineral difficult. Hardness is approximately 6 on Mohs' scale, and density is 4.03 g/cm^3, determined on a modified Roller-Smith balance. The measured density agrees well with the calculated figure of 4.07 g/cm^3.

The mineral is uniaxial (−), showing strong anomalous blue-violet and golden-yellow interference colors. Refractive indices determined with sodium-vapor light are $\omega=1.685\pm0.002$ and $\epsilon=1.674\pm0.002$, with low birefringence; dichroism absent. Most of the grains contain minute bubble and solid inclusions. Known physical and optical properties and chemical composition of this material are listed in Table 1, with the corresponding data for benitoite added for comparison. The optics suggest that at some composition the material is isotropic.

CHEMISTRY

Pabstite from Santa Cruz has been analyzed with an A.R.L. electron-probe microanalyzer (Table 2). No elements possessing atomic numbers greater than 10 (other than those listed) were detected by the micro-

TABLE 2. ANALYSIS OF PABSTITE FROM SANTA CRUZ

	Wt. %
SiO_2	37.7
TiO_2	3.8
SnO_2	24.4
BaO	33.2
Total	99.1

probe; detection limits are 0.01% for most elements, but rise from this value to 0.1% from Si(14) to Na(11). Some antipathetic variation of Ti and Sn was found from point to point, amounting to approximately ±0.5% TiO_2 and ±1% SnO_2. SiKα, TiKα, and BaLβ_2 lines were standardized with natural benitoite, which was considered as pure $BaTiSi_3O_9$, an assumption that appears reasonable judging from the analyses of Blasdale (Louderback, 1909). Cassiterite free from Fe, Mn, W, and Ta impurities was used for the Sn determination. Corrections were made for background, *x*-ray absorption, and atomic number (using tables prepared by I. Adler), except in the case of Sn. Because of the large difference in mean atomic number between pabstite (30) and cassiterite (41), it was preferred for the Sn determination to use tables by Colby and Niedermeyer (1964) for absorption and an expression for the atomic number correction by Reed and Long (unpublished).

TABLE 3. CELL DATA FOR BENITOITE, PABSTITE, AND $BaSnSi_3O_9$

	Benitoite	Pabstite	$BaSnSi_3O_9$
a (Å)	6.6410 ± 0.0007	6.706 ± 0.002	6.724 ± 0.002
c (Å)	9.7597 ± 0.0010	9.829 ± 0.002	9.854 ± 0.002
Volume of cell (Å^3)	372.77	382.76	385.83
Cell content	$2(BaTiSi_3O_9)$	$2[Ba(Sn, Ti)Si_3O_9]$	$2(BaSnSi_3O_9)$
Measured density	3.65 g/cm^3	4.03 g/cm^3	—
Calculated density	3.68 g/cm^3	4.07 g/cm^3	4.17 g/cm^3
Space group	$P\bar{6}c2$	$P\bar{6}c2$	—

On the basis of nine oxygens, the analysis in Table 2 can be recast to $Ba_{1.03}Sn_{0.77}Ti_{0.23}Si_{2.99}O_9$, which clearly shows the analogy with benitoite, $BaTiSi_3O_9$. Thus, an ideal formula of $Ba(Sn_{0.77}Ti_{0.23})Si_3O_9$ may be applied to the titanian pabstite from Santa Cruz.

Despite the close similarities in charge and ionic size ($Sn^{4+} = 0.71$ Å, $Ti^{4+} = 0.68$ Å), appreciable substitution of Sn for Ti seems to have been recorded rarely. Ramdohr (1936) described a variety of sphene containing at least 10% Sn from Arandis, S. W. Africa. SnO_2 in benitoite from Fresno County, California was found with the electron probe to range from zero to 4.1%, that is, up to 11.4% substitution of pabstite for benitoite. The benitoite of the type locality is completely free of Sn.

Pure barium tin silicate has been synthesized from a mixture of stoichiometric composition in a simple hydrothermal apparatus at 330° C. and saturated-water-vapor pressure. Large crystals of sanbornite, $BaSi_2O_5$, were produced at the same time; however, the crystals of $BaSnSi_3O_9$ were

TABLE 4. COMPARISON OF OBSERVED POWDER LINES. CuKα RADIATION

hkl	Pabstite		$BaSnSi_3O_9$		Benitoite	
	d Å meas.	I obs.	d Å meas.	I obs.	d Å meas.	I obs.
100	5.829	30	5.848	35	5.750	30
002	4.910	15	4.933	20	4.880	7
102	3.762	100	3.770	100	3.723	100
110	3.363	30	3.370	50	3.326	25
111	3.181	10	3.192	15	3.148	20
200	2.912	18	2.917	20	2.875	35
112	2.775	90	2.784	90	2.747	90
202	2.505	3	2.512	8	2.481	13
004	2.465	15	2.465	22	2.436	18
104	2.267	5	2.273	7	2.243	15
210	2.204	15	2.206	17	2.175	25
211	2.131	5	2.132	10	2.122	15
212	2.012	faint	2.014	8	1.987	20
114	1.987	20	1.989	30	1.966	25
300	1.941	13	1.950	20	1.916	15
204	1.881	15	1.883	20	1.860	17
213	—		1.857	very faint	1.807	3
302	1.807	17	1.811	22	1.784	20
220	1.682	7	1.682	12	1.662	10
006 214	1.643	15	1.643	20	1.622	20
310	1.614	very faint	1.619	5	1.598	very faint
311	1.591	15	1.594	18	1.574	20
222	not resolved				not resolved	
106			1.581	10		
312	1.535	13	1.539	15	1.518	20
304	not resolved		1.527	15	not resolved	
116	1.476	15	1.477	20	1.460	20

not of a size suitable for single-crystal examination. Synthesis was also successfully carried out at 500° C. and 15,000 psi; again, sanbornite was present. No other phases appeared to be present.

X-RAY CRYSTALLOGRAPHY

X-ray diffraction patterns of pabstite are very similar to those of benitoite, but relatively minor changes in the intensity of certain lines and small changes in spacings were observed in powder photographs. Examination of single-crystal photographs taken with both the Weissenberg and precession devices confirm the similarity; at the same time, those spectra most affected by the substitution of Sn for Ti are clearly discernible.

The space group for pabstite has been deduced as $P\bar{6}c2$, the same as that of benitoite. The pertinent crystallographic data for benitoite, pabstite, and synthetic $BaSnSi_3O_9$ are listed in Table 3. Cell dimensions for pabstite and benitoite were determined from single-crystal observations, those of $BaSnSi_3O_9$ from powder lines in which the Kα components were resolved. The refined data for benitoite are from Fischer (1964). A comparison of observed powder lines for benitoite, pabstite, and $BaSnSi_3O_9$ is presented in Table 4. Line intensities were estimated by visual comparison with a film of scaled densities.

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