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## THE BABINGTONITE OF FIGLINE (PRATO), ITALY

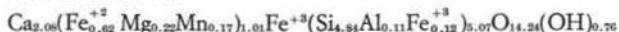
RIASSUNTO. — Viene descritto un nuovo ritrovamento di Babingtonite. Il minerale proviene da Figline (Prato), Italia e si trova in vene di quarzo e prehnite, associato con diabase a pillow.

Del minerale sono riportati i dati morfologici, cristallografici, ottici e chimici.

In particolare, viene proposto uno spettro di polvere parzialmente diverso da quello fornito in letteratura. Il diffrattogramma è indicizzato, oltre che su una base geometrica, tenendo conto delle intensità calcolate sulla base dei fattori di struttura.

I parametri raffinati di cella sono:  $a = 7.455(3)$ ,  $b = 11.612(5)$ ,  $c = 6.672(4)$ ,  $\alpha = 91^\circ 30'(4)$ ,  $\beta = 93^\circ 49'(3)$ ,  $\gamma = 104^\circ 10'(2)$  con P1 o P1 come possibile gruppo spaziale.

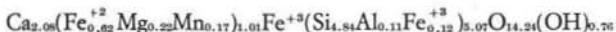
La formula cristallografica è:



con una densità calcolata  $d_{\text{calc.}} = 3.419 \text{ g cm}^{-3}$  ( $Z = 2$ ) e una densità osservata  $d_{\text{obs.}} = 3.31 \text{ g cm}^{-3}$ .

ABSTRACT. — A new finding of babingtonite in Figline (Prato), Italy, is described. The mineral occurs in quartz and prehnite veins, associated with pillow diabase.

Crystallographic, optical and chemical data are reported. A powder pattern is given somewhat different from the literature one. The powder pattern has been indexed utilizing unit cell data and peak intensities computed from structure factors. The crystal chemical formula is:



with  $d_{\text{calc.}} = 3.419 \text{ g cm}^{-3}$  ( $Z = 2$ ) and  $d_{\text{obs.}} = 3.31 \text{ g cm}^{-3}$ .

The refined unit cell parameters are:  $a = 7.455(3)$ ,  $b = 11.612(5)$ ,  $c = 6.672(4)$ ,  $\alpha = 91^\circ 30'(4)$ ,  $\beta = 93^\circ 49'(3)$ ,  $\gamma = 104^\circ 10'(2)$  with P1 or P1 as possible space groups.

### Introduction

Babingtonite is a pyroxenoid, described as «Fünfer- Einketten» in the classification scheme proposed by LIEBAU (1969).

It has been found in many localities, occurring in skarn deposits, diabase formations and granitic pegmatites (a listing of the findings is given by VINOGRADOVA et al. (1966) and VERKAEREN (1974)).

Recently, we identified as babingtonite a mineral given to us by the collectors of the G.R.G. (Gruppo Ricerche Geologiche) of Prato.

It was found in a quarry near Figline (Prato), Italy. The mineral occurs in

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veins of quartz and prehnite, associated with the pillow diabase of the ophiolitic complex of Monte Ferrato.

While studying the mineral, we had the opportunity to make a revision of its properties. In particular, the literature data on the X-ray powder diffraction pattern (SABINA and TRAILL, 1960) are somewhat incorrect, either for peak positions or their indices.

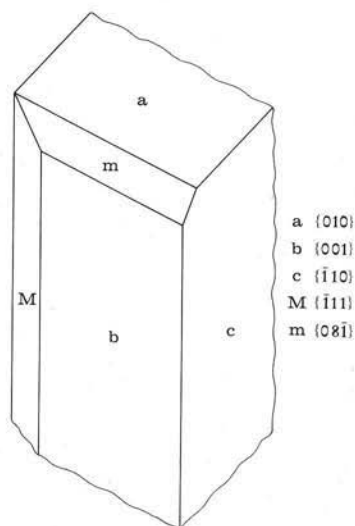


Fig. 1.

## Morphology

Babingtonite from Figline is dark-green to black. As the mineral is embedded in the prehnite-quartz matrix, a few crystals were suitable to morphological study. A fragment of nearly  $2.5 \times 1 \times 1 \text{ mm}^3$  was mounted on a two circles goniometer; its morphology is depicted in fig. 1. As shown, the crystal exhibits a prismatic habit and is elongated along  $[110]$ . The forms present are  $\{010\}$ ,  $\{001\}$ ,  $\{\bar{1}10\}$ ,  $\{\bar{1}11\}$ ,  $\{08\bar{1}\}$ . To evidence the prismatic habit the crystal has not been drawn in the normal setting.

## Optical properties

Optical properties of the Figline babingtonite are given in table 1, together with some selected literature data. Pleochroism and optical axial angle were

TABLE 1  
*Optical properties*

Babingtonite from Figline			Literature data	
	refr. indices	pleochroism	refr. indices	pleochroism
$\alpha$	1.719	emerald green	1.713 - 1.716	emerald green
$\beta$	1.729	lilac	1.725 - 1.730	lilac
$\gamma$	1.746	light brown	1.746 - 1.750	light brown
$2V_{\gamma}$	$72^{\circ} \pm 1$		$75^{\circ}$	

measured at the universal stage.  $\alpha$  and  $\beta$  refraction indices were measured for sodium light. The reported  $\gamma$  value has been computed.

### X-ray crystallography

The X-ray powder diffraction pattern was obtained by Mn filtered  $\text{FeK}\alpha$  radiation, with a Philips PW 1050 diffractometer, scan speed  $0.5^\circ \text{ min}^{-1}$ , time constant  $\tau = 4 \text{ sec.}$  up to  $2\theta = 100^\circ$ . It is reported in table 2, together with the pattern given by SABINA and TRAILL (1960) and reported in A.S.T.M. (now J.C.P.D.S.) card n.° 14-321.

The two patterns are somewhat different. The main differences are the doubling of the peak at  $d = 6.69 \text{ \AA}$  of SABINA and TRAILL's pattern in two peaks with  $d = 6.89$  and  $d = 6.65 \text{ \AA}$ , the presence in our pattern of additional peaks (as the strong diffractions at  $d = 3.32$  and  $d = 3.004 \text{ \AA}$ ) and different peak intensities.

The difference was large enough to hinder a routine identification on the basis of the strongest X-ray powder diffraction peaks.

Therefore, we studied the mineral by X-ray single crystal diffraction techniques, determining that it was babingtonite on the basis of the diffraction symmetry and unit cell parameters.

Then we recorded the X-ray powder diffraction patterns of babingtonite samples from Baveno (Italy) and Arendahl (Norway): the patterns were identical with that obtained on babingtonite from Figline.

Although a routine identification on the basis of the pattern given by SABINA and TRAILL (1960) was unsuccessful, the examination of their pattern shows that it can be related to our one, without too large discrepancies, if we take into account the worse experimental conditions utilized by the quoted authors, namely Debye-Scherrer camera with diameter of 57.54 mm and  $\text{CuK}\alpha$  radiation (less resolution and higher absorption). This removes any doubt on the nature of their sample.

We remark that our pattern is fully comparable with that obtained by VINOGRADOVA et al. (1966) on a Mn-rich babingtonite (7.91 wt.% MnO), which they called manganobabingtonite; unfortunately, their paper reports only unindexed interplanar spacings with  $d$  less than  $3.442 \text{ \AA}$ .

The refinement of the lattice parameters, estimated from single crystals photographs, by least squares fitting of the  $2\theta$  values measured in X-ray powder diffraction pattern, was unsuccessful for the presence of too many  $2\theta$  calculated values spreaded around the observed value.

We indexed the powder pattern on the basis of the intensities calculated from the structure factors reported by ARAKI and ZOLTAI (1972) in their paper on crystal structure of babingtonite.

We were able to univocally index 28 peaks, which we used in the least squares refinement of the unit cell of babingtonite from Figline from Baveno and from Arendahl. The refined parameters are reported in table 3.

We used the reduced cell given by ARAKI and ZOLTAI (1972) and formerly adopted by RICHMOND (1937). The last author gives the transformation matrices to other cells previously used in morphological studies on babingtonite.

TABLE 2  
X-ray powder diffraction pattern of babingtonite

Babingtonite from Figline					Sabina and Traill (1960)	
$d_{\text{obs.}}$	$d_{\text{calc.}}$	hkl	$(I/I_0)_{\text{obs.}}$	$(I/I_0)_{\text{calc.}}$	$d_{\text{obs.}}$	$(I/I_0)_{\text{obs.}}$
11.17	11.25	010	4	19	-	-
6.88	6.89	110	42*	14	-	-
6.63	6.65	001	75*	20	6.69	40
5.08	5.08	$\bar{1}01$	3	2	-	-
4.71	{ 4.71	101	3	3	-	-
	{ 4.68	$\bar{1}\bar{1}\bar{1}$		3	-	-
4.41	4.40	111	3	7	4.47	38
4.06	4.06	$\bar{1}21$	11	10	4.07	40
3.98	3.98	120	1	3	-	-
	{ 3.738	030		2		
3.707	{ 3.735	$\bar{1}30$	3	4	3.75	40
	{ 3.702	$\bar{2}10$		2		
3.442	3.446	$\bar{2}20$	47*	10	3.45	40
3.320	3.325	002	22*	5	-	-
3.268	{ 3.274	201		3		
	{ 3.256	$\bar{1}31$	6	3	3.27	20
3.148	{ 3.152	012		4		
	{ 3.156	$\bar{2}\bar{1}\bar{1}$	6	2	-	-
3.110	3.110	102	68	24	3.12	70
3.050	3.049	$\bar{1}12$	6	4	-	-
2.945	{ 2.948	$\bar{1}\bar{1}\bar{2}$		16		
	{ 2.943	$\bar{1}\bar{1}\bar{2}$	100	23	2.95	60B
2.872	2.871	140	18	28	2.87	80
2.740	2.742	220	26	27	2.75	100
2.620	2.622	141	4	12	2.63	30
2.559	2.557	$\bar{2}12$	8	7	2.56	20
2.477	2.478	$\bar{3}10$	5	5	2.47	50
2.464	2.466	122	8	16	-	-
2.437	2.438	$\bar{3}20$	19	8	-	-
2.271	2.272	311	2	2	2.33	10
2.240	2.239	310	3	7	2.24	10
2.195	{ 2.193	0 $\bar{1}$ 3		6		
	{ 2.195	042	8	8	2.20	10
2.165	{ 2.165	103		9		
	{ 2.164	250	21	7	2.17	60
2.101	2.103	340	2	2	-	-
2.073	2.073	311	1	6	2.07	30

Different cells were chosen by SABINA and TRAILL (1960) (their cell transforms to our one by  $101/0\bar{1}0/00\bar{1}$ ) and by KOSOI (1974) (which transforms to our one by  $00\bar{1}/101/0\bar{1}0$ ).

A brief comment must be made about the calculated intensities reported in table 2. After Lorentz-polarization corrections, the calculated intensities were normalized imposing that  $\Sigma(I/I_0)_{\text{obs.}} = \Sigma I_{\text{calc.}}$ . The fitting was not satisfactory as regard the peaks  $\bar{1}10$ , 001,  $\bar{2}20$ , 002, which correspond to cleavage planes and may be enhanced by preferred orientation effects.

A new normalization similar to the preceding was applied, after elimination of these four peaks from the sums. These results are reported in table 2. The fitting, is now fair, except for reflections at  $d = 3.110$  and  $d = 2.945$  Å, which show observed intensity greater than the calculated value.

Babingtonite from Figline					Sabina and Traill (1960)	
d <sub>obs.</sub>	d <sub>calc.</sub>	hkl	(I/I <sub>o</sub> ) <sub>obs.</sub>	(I/I <sub>o</sub> ) <sub>calc.</sub>	d <sub>obs.</sub>	(I/I <sub>o</sub> ) <sub>obs.</sub>
2.057	2.056	2 $\bar{5}$ 1	1	6	-	-
2.022	2.022	322	6	4	2.02	10
1.958	1.958	213	2	2	1.965	10
		151		1		
1.804	1.804	252	2	1	1.809	40
		430		1		
		233		3		
		342		1		
		400		1		
		322		2		
1.714	1.714	160	1	8	1.716	10
1.683	1.682	243	1	3	-	-
		352		3		
1.658	1.658	332	4	4	1.662	30
		014		3		
		361		6		
1.638	1.637	161	3	5	1.641	30
		153		4		
1.616	1.614	450	2	1	-	-
		024		1		
		071		1		
1.576	1.575	412	3	3	1.580	20
		124		2		
		323		1		
1.562	1.563	333	3	4	1.566	10
		402		3		
1.536	1.537	402	1	3	-	-
1.493			1		1.504	10
1.472			2		1.478	10
1.455			1		1.458	10
1.431			2		1.430	
1.428			2		-	-
1.421			2		-	-
1.399			1		1.403	20
1.388			10		1.390	20
1.365			1		1.369	20
					1.337	20
* 1.319			2		1.320	20

TABLE 4  
Chemical data

	Wt %	atomic ratios
SiO <sub>2</sub>	50.40	4.84
TiO <sub>2</sub>	0.04	-
Al <sub>2</sub> O <sub>3</sub>	0.96	0.11
FeO	7.76	0.62
Fe <sub>2</sub> O <sub>3</sub>	15.57	1.1'
MnO	2.07	0.17
MgO	1.59	0.22
CaO	20.22	2.08
H <sub>2</sub> O	1.19	(OH) 0.76

TABLE 3  
Lattice parameters of babingtonite

	Figline		Baveno		Arendahl	
	P1 or P1̄	P1 or P1̄	P1 or P1̄	P1 or P1̄	P1 or P1̄	P1 or P1̄
Space group	P1 or P1̄	P1 or P1̄	P1 or P1̄	P1 or P1̄	P1 or P1̄	P1 or P1̄
a (Å)	7.455(3)	7.465(3)	7.468(2)			
b	11.612(5)	11.624(8)	11.640(4)			
c	6.672(4)	6.683(4)	6.683(3)			
α	91°30'(4)	91°35'(4)	91°36'(4)			
β	93°49'(3)	93°48'(3)	93°53'(2)			
γ	104°10'(2)	104°13'(2)	104°16'(2)			
V(Å <sup>3</sup> )	558.3(4)	560.3(4)	561.1(3)			

### Chemical data

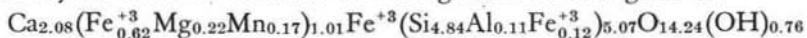
Babingtonite was carefully separated from quartz and prehnite by picking under microscope.

Chemical analysis (for MgO, Al<sub>2</sub>O<sub>3</sub>, SiO<sub>2</sub>, K<sub>2</sub>O, CaO, TiO<sub>2</sub>, MnO, Fe<sub>2</sub>O<sub>3</sub>) was carried out by X-ray fluorescence spectrometry following the analytical procedure developed by FRANZINI and LEONI (1972) and modified by LEONI and SAITTA (1974). H<sub>2</sub>O content was determined by gaschromatographic microelemental analysis.

Results are listed in table 4, together with the chemical formula, calculated on the basis of 15 O in the asymmetrical unit of the P $\bar{1}$  unit cell.

As total Fe was determined as Fe<sub>2</sub>O<sub>3</sub>, the ripartition between Fe<sup>+2</sup> and Fe<sup>+3</sup> was made to saturate the different coordination polyhedra of the structure.

The crystal chemical formula of babingtonite from Figline is:



The calculated density is 3.419 g cm<sup>-3</sup>, whereas the observed value is 3.31 ± 0.02 g cm<sup>-3</sup>.

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