FAHEYITE, A NEW PHOSPHATE MINERAL FROM THE SAPUCAIA PEGMATITE MINE, MINAS GERAIS, BRAZIL*

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Abstract

Faheyite, a new mineral from the Sapucaia pegmatite mine, Minas Gerais, Brazil, has the composition $(Mn,Mg,Na)Be_2Fe_2(PO_4)_4 \cdot 6H_2O$. It occurs in vugs as white, bluish-white, or brownish-white tufted fibers that coat other minerals, such as muscovite, quartz, variscite, and frondelite.

The powder pattern of faheyite has been completely indexed on the basis of a primitive hexagonal cell with dimensions: $a_0 = 9.43$ Å and $c_0 = 16.00$ Å. The powder film was compared with a rotation picture of a fiber taken in the powder camera, as an aid to indexing the powder film. *X*-ray powder photographs show strong lines at 5.72, 7.28, 3.243, 3.087, 3.031, and 3.958 Å. The measured specific gravity is 2.660, and the specific gravity calculated from *x*-ray data is 2.670. Indices of refraction are $\omega = 1.631$ and $\epsilon = 1.652$.

Chemical analysis gave the following percentages: insoluble 9.44, P_2O_5 38.11, Fe_2O_3 21.42, Al_2O_3 0.10, Mn_2O_3 none, FeO none, BeO 7.26, MnO 5.99, MgO 1.14, Na_2O 0.84, K_2O trace, F trace, H_2O 14.90; total 99.20.

The mineral is named in honor of Joseph J. Fahey, geochemist of the U. S. Geological Survey.

Introduction

In the period 1943 to 1945, William T. Pecora, of the U. S. Geological Survey, and A. L. de M. Barbosa, of the Departamento Nacional da Producção Mineral, Brazil, made several examinations of the Sapucaia pegmatite mine, near Conselheiro Pena, Minas Gerais, Brazil, and collected a representative suite of minerals for later study. These minerals have been under investigation in the laboratory of the U. S. Geological Survey since 1947. The present paper describes a new phosphate mineral, the second new mineral from this locality (Lindberg, 1949). A complete description of the pegmatite and its minerals will appear in a forthcoming paper.

Faheyite is a hydrous beryllium-manganese-iron phosphate with the formula $(Mn,Mg,Na)Be_2Fe_2(PO_4)_4 \cdot 6H_2O$. It is named in honor of Joseph J. Fahey, of the Geochemistry and Petrology Branch, U. S. Geological Survey, in recognition of his contributions to the chemistry of minerals and of the guidance he has given to younger chemists engaged in the analytical chemistry of minerals.

Occurrence and Physical Properties

Faheyite occurs in vugs as white, bluish-white, or brownish-white fibers coating other minerals. Botryoidal masses of fibers completely

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enclose euhedral quartz crystals or are attached to surfaces of muscovite sheets. Flat rosettes of fibers lie between sheets of muscovite, and tufts of fibers occur on crystals of variscite, on botryoidal frondelite, and between layers of frondelite.

Individual fibers of faheyite average about 0.08 mm. in length and 0.01 mm. in thickness. The fibers usually grow normal to the surfaces of other minerals and may be singly terminated by pyramid faces.

Faheyite is uniaxial (+); $\omega=1.631$ and $\epsilon=1.652$; $\epsilon-\omega=0.021$; elongation is parallel to the c-axis; cleavage, perfect and parallel to c-axis.

The specific gravity was measured on the sample used for analysis by means of an Adams Johnston pycnometer of fused silica; it was found to be 2.660 at 4° C. This sample contains 9.44% insoluble matter, which consists chiefly of quartz, with a minor amount of muscovite. The specific gravity was not corrected for the insoluble matter, since the specific gravity of faheyite is essentially the same as that of quartz. The specific gravity calculated from x-ray data is 2.670.

Chemical Composition

Faheyite is essentially a hydrous beryllium-manganese-iron phosphate, with the formula $(Mn,Mg,Na)Be_2Fe_2'''(PO_4)_4 \cdot 6H_2O$. Its chemical analysis, ratios, calculated equivalents, and atoms per unit cell are listed in Table 1. The number of atoms of each type are calculated by multiplying the equivalents by 0.01 to convert from a percentage to a fractional scale, and by 1975, the unit-cell weight expressed on a chemical scale against $O=16$. The role that sodium plays in the mineral is uncertain; but sodium probably substitutes for divalent manganese, which has a similar ionic radius. If such a substitution occurs, the number of atoms in the unit cell in the manganese position (Mn, Mg, Na) becomes a whole number.

At the Sapucaia pegmatite mine, beryllium occurs in small quantities in phosphate minerals associated with faheyite. Spectrographic work shows 0.0X% Be in frondelite and 0.0X% to 0.X% Be in variscite.

Faheyite is slowly dissolved by hot dilute HCl, HNO_3, and H_2SO_4.

X-Ray Data

This beryllium-manganese-iron phosphate occurs as minute fibers; these failed to give any reflection in single crystal studies, and the Laue symmetry is not known. Carefully selected parallel bundles of fibers gave good rotation photographs around the c-axis, although the spots representing various families of planes were spread through a small arc. Every Weissenberg photograph taken showed a completely random orientation perpendicular to the fiber axis.

TABLE 1. CHEMICAL ANALYSIS AND FORMULA OF FAHEYITE

	Analysis	Recalculated after Deducting Insoluble	Ratios	Oxygen Equivalent	Metal Equivalent	Atoms: Metals and Water per Unit Cell
Insol.*	9.44					
P_2O_5	38.11	42.08	0.2964	1.4821	0.5928	11.71
Fe_2O_3	21.42	23.65	0.1481	0.4443	0.2962	5.85
Al_2O_3	0.10	0.11	0.0011	0.0032	0.0021	0.04
Mn_2O_3	None	None				
FeO	None	None				
BeO	7.26	8.02	0.3205	0.3205	0.3205	6.33
MnO	5.99	6.61	0.0932	0.0932	0.0932	1.84
MgO	1.14	1.26	0.0313	0.0313	0.0313	0.62
Na_2O	0.84	0.93	0.0150	0.0150	0.0300	0.59
K_2O	Trace	Trace				
F	Trace	Trace				
H_2O	14.90	16.45	0.9131			18.03
	99.20	99.11				

M. L. Lindberg, analyst. Analysis on 1.2 grams.

Alkali determination by flame photometer by E. Nygaard. A spectrogram by K. J. Murata gives in addition 0.X% Ca, 0.0X% Ti, Zn, and Pb, and 0.00X% Co, Sr, and Ba. Elements looked for but not found: Cu, Ag, Bi, As, Sb, Sn, Cd, Tl, Ce, In, Ga, Mo, W, Bi, V, Cr, Zr, Cb, La, Y, Sc, and B.

* Insoluble consists of quartz and muscovite.

The rotation photographs were used in conjunction with the powder photographs as an aid to indexing the latter. In a hexagonal mineral

$$\frac{1}{d^2_{hkl}} - \frac{l^2}{c^2} = \frac{4}{3}\,\frac{(h^2 - hk + k^2)}{a^2};$$

in faheyite $1/d^2_{hkl}$ was obtained by measuring the powder photograph, and l^2/c^2 for each *hkl* plane was obtained in the following manner: Rotation photographs around the fiber *c*-axis were taken both in the powder and in the rotation cameras. The rotation photographs from the powder camera were aligned with the powder pictures from the same camera, and the *l*-index corresponding to a given line on the powder photograph was found. Photographs taken with iron radiation gave indices of $l=0$, 1, and 2 (Fig. 1); photographs taken with copper radiation gave indices of $l=0$, 1, 2, and 3. The higher values of l were obtained by the use of the Bernal chart in conjunction with the regular rotation photograph. For points outside the sphere of reflection, that rotate

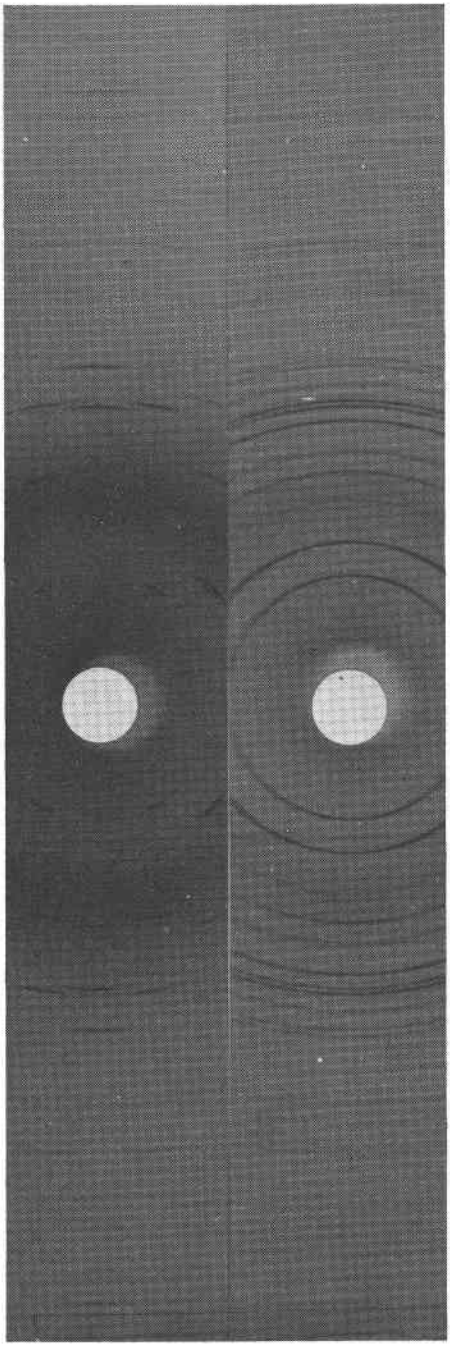

FIG. 1. Powder and rotation photographs of faheyite, powder camera. (Iron radiation, manganese filter.)

about the c-axis, the l-index was found by calculation after the value for a_0 had been established.

To find a_0 the equation

$$\frac{1}{d^2_{h0l}} - \frac{l^2}{c^2} = \frac{4}{3}\frac{h^2}{a^2}$$

was solved for 21 reflections indexed as 101, 102, 103, 104, 105, 107, 201, 203, etc., and an average value of 0.014984 for $4/3a^2$ was obtained. This value was used to find the calculated values of d_{hkl} according to the equation:

$$\frac{1}{d^2_{hkl}} = 0.014984\,(h^2 + hk + k^2) + \frac{l^2}{c^2}.$$

This solves to $d_{100} = 8.17$ Å and $a_0 = 9.43$ Å. The value for c_0 obtained from the layer line separation on the rotation pattern was in good agreement with the c_0 derived from the 002 and 004 spacings on the powder photograph, and there were no consistent variations between measured and calculated $\frac{1}{d^2_{hkl}}$ for higher values of l^2/c^2. The cell volume is 1233 Å^3.

All spots were indexed, and no systematic absences were observed; the pattern indicates a primitive unit cell. Calculated and measured values for d are given in Table 2.

Conclusions

Faheyite is a hydrous phosphate that formed late in the mineral sequence of the Sapucaia granitic pegmatite. Other phosphate minerals in this pegmatite are triphylite, heterosite, vivianite, frondelite, roscherite, childrenite, hureaulite, apatite, and variscite. Faheyite has no apparent structural relationship to these or to other phosphate minerals recorded in the available literature.

Acknowledgments

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Reference

Lindberg, Marie Louise (1949), Frondelite and the frondelite-rockbridgeite series: *Am. Mineral.*, **34**, 541–549.

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Table 2. X-ray Powder Spacing Data for Faheyite

(Iron radiation, manganese filter, $\lambda=1.9373$)
$a_0=9.43$ Å, $c_0=16.00$ Å, $V=1233$ Å^3

Intensity	d (meas.) Å	Indices		d (calc.)	Indices		d (calc.)	Indices		d (calc.)
		hkl	hkil		hkl	hkil		hkl	hkil	
½	8.00	002*	0002*	8.00						
9	7.28	101	$10\bar{1}1$	7.28						
10	5.72	102	$10\bar{1}2$	5.72						
½	4.68	110	$11\bar{2}0$	4.72						
2	4.53	111	$11\bar{2}1$	4.52						
½	4.47	103	$10\bar{1}3$	4.47						
½	4.02	004*	0004*	4.00						
5	3.962	201	$20\bar{2}1$	3.958						
2	3.636	202	$20\bar{2}2$	3.638						
2	3.591	104	$10\bar{1}4$	3.593						
½	3.536	113	$11\bar{2}3$	3.533						
6	3.244	203	$20\bar{2}3$	3.243						
½	3.173	005*	0005*	3.200						
6	3.085	210	$21\bar{3}0$	3.087						
6	3.029	211	$21\bar{3}1$	3.031						
2	2.986	105	$10\bar{1}5$	2.981						
2	2.877	212	$21\bar{3}2$	2.880						
2	2.856	204	$20\bar{2}4$	2.858						
3	2.724	300	$30\bar{3}0$	2.723						
3	2.673	213	$21\bar{3}3$	2.672	006*	0006*	2.666			
½	2.583	302	$30\bar{3}2$	2.578						
½	2.531	106*	$10\bar{1}6$*	2.535						
½	2.449	214	$21\bar{3}4$	2.444						
½	2.424	303	$30\bar{3}3$	2.425						
½	2.365	220	$22\bar{4}0$	2.364						
½	2.325	116	$11\bar{2}6$	2.322						
1	2.264	310	$31\bar{4}0$	2.266	222	$22\bar{4}2$	2.262			
1	2.246	311	$31\bar{4}1$	2.243						
½	2.202	107*	$10\bar{1}7$*	2.200						

TABLE 2—(*Continued*)

Intensity	d (meas.) Å	Indices *hkl*	Indices *hkil*	d (calc.)	Indices *hkl*	Indices *hkil*	d (calc.)	Indices *hkl*	Indices *hkil*	d (calc.)
½	2.182	312	$31\bar{4}2$	2.180						
1	2.160	223	$22\bar{4}3$	2.157						
½	2.080	313	$31\bar{4}3$	2.086						
1	2.060	117*	$11\bar{2}7$*	2.057						
2	2.027	224	$22\bar{4}4$	2.031	401	$40\bar{4}1$	2.026	216	$21\bar{3}6$	2.018
1	1.973	314	$31\bar{4}4$	1.971						
1	1.944	108*	$10\bar{1}8$*	1.943						
2	1.906	403	$40\bar{4}3$	1.907	306	$30\bar{3}6$	1.905			
½	1.859	321	$32\bar{5}1$	1.861						
½	1.849	315	$31\bar{4}5$	1.849						
2	1.824	322	$32\bar{5}2$	1.825						
½	1.786	410	$41\bar{5}0$	1.783						
1	1.769	411	$41\bar{5}1$	1.771	323	$32\bar{5}3$	1.768			
1	1.740	412	$41\bar{5}2$	1.740	109*	$10\bar{1}9$*	1.737			
1	1.721	405	$40\bar{4}5$	1.722						
2B	1.693	324	$32\bar{5}4$	1.697	413	$41\bar{5}3$	1.691			
2B	1.629	500	$50\bar{5}0$	1.634	501	$50\bar{5}1$	1.625	406	$40\bar{4}6$	1.622[a]
2B	1.573	330	$33\bar{6}0$	1.576						
½	1.559	503	$50\bar{5}3$	1.562	415	$41\bar{5}5$	1.557			
½	1.538	332	$33\bar{6}2$	1.543						
½	1.529	326	$32\bar{5}6$	1.533						
½	1.513	333	$33\bar{6}3$	1.508	11.10*	$11\bar{2}.10$*	1.515			
1B	1.487	20.10*	$20\bar{2}.10$*	1.490	416	$41\bar{5}6$	1.483			
1B	1.464	510	$51\bar{6}0$	1.467	334	$33\bar{6}4$	1.463	511	$51\bar{6}1$	1.462
½	1.441	244	$24\bar{6}4$	1.440						
½	1.407	513	$51\bar{6}3$	1.414	415	$41\bar{5}5$	1.407			

* This index corresponds to a point that was outside the sphere of reflection when the crystal was rotated about *c*-axis and hence was not observed on the rotation picture.

The powder film was calibrated against shrinkage by addition of Ag metal to the spindle of faheyite. This calibration was made at the suggestion of C. L. Christ. The agreement of calculated and observed d values show that any errors involved in determining the cell edges are less than the errors reading 2θ to ± 0.1 mm. (camera diameter 114.59 mm.).

TABLE 2—(*Continued*)

Intensity	*d* (meas.) Å	Indices *hkl*	Indices *hkīl*	*d* (calc)	Indices *hkl*	Indices *hkīl*	*d* (calc.)	Indices *hkl*	Indices *hkīl*	*d* (calc.)
½	1.388	11.11*	11$\bar{2}$.11*	1.390	506	50$\bar{5}$6	1.393			
½	1.376	514	51$\bar{6}$4	1.377						
½	1.366	20.11*	20$\bar{2}$.11	1.370						
½	1.357	601	60$\bar{6}$1	1.357						
1B	1.333	341	34$\bar{7}$1	1.338	246	24$\bar{6}$6	1.366	515	51$\bar{6}$5	1.334[b]
½	1.314	603	60$\bar{6}$3	1.319	10.12*	10$\bar{1}$.12*	1.316			
½	1.300	343	34$\bar{7}$3	1.302						
½	1.285	516	51$\bar{6}$6	1.285						
3	1.268	253	25$\bar{7}$3	1.270	20.12*	20$\bar{2}$.12	1.267			
½	1.251	605	60$\bar{6}$5	1.253						
½	1.241	611	61$\bar{7}$1	1.242	345	34$\bar{7}$5	1.238			
½	1.230	612	61$\bar{7}$2	1.231						
½	1.221	248*	24$\bar{6}$8	1.222						
½	1.210	32.10	32$\bar{5}$.10	1.217						
½	1.173	441	44$\bar{8}$1	1.176						
½	1.139	703	70$\bar{7}$3	1.140	353	35$\bar{8}$3	1.140			
½	1.129	616	61$\bar{7}$6	1.129						
½	1.119	262	26$\bar{8}$2	1.122	704	70$\bar{7}$4	1.120	354	35$\bar{8}$4	1.120[c]
½	1.104	20.14*	20$\bar{2}$.14*	1.101						
½	1.085	50.11*	50$\bar{5}$.11*	1.086						
½	1.080	710	71$\bar{8}$0	1.082	711	71$\bar{8}$1	1.080	51.10*	51$\bar{6}$.10*	1.081
½	1.068	41.12	41$\bar{5}$.12	1.068	33.11	33$\bar{6}$.11	1.068			
½	1.042	451	45$\bar{9}$1	1.044	714	71$\bar{8}$4	1.044	11.15*	11$\bar{2}$.15*	1.040
½	1.025	453	45$\bar{9}$3	1.026						
½	1.009	363	36$\bar{9}$3	1.010	24.12*	24$\bar{6}$.12	1.009			

Additional possible reflections:
a 209* 20$\bar{2}$9* 1.629
b 00.12* 000.12* 1.333
c 33.10* 33$\bar{6}$.10* 1.121
B broad reflection.