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The mineralogy of väyrynenite, (Mn,Fe) Be (PO_4) (OH)*

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With 3 figures

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Auszug

Es wird über eine neue chemische Analyse und über die kristallographische Untersuchung an Einzelkristallen des Väyrynenits von Eräjärvi im zentralen Finnland berichtet. Die Analyse ergab: MnO 34,01, FeO 5,92, CaO 0,53, BeO 13,85, Na_2O 0,20, K_2O 0,04, Al_2O_3 0,40, P_2O_5 39,98, H_2O+ 4,93, H_2O- 0,19, unlösl. 0,06. Die Raumgruppe ist $P\,2_1/a - C_{2h}^5$; die Gitterkonstanten sind $a = 5{,}41_1 \pm 0{,}005$ Å, $b = 14{,}49 \pm 0.02$ Å, $c = 4{,}73_0$ Å $\pm 0{,}005$ Å, $\beta = 102° 45' \pm 5'$. Die Zelle enthält 4 Formeleinheiten (Mn,Fe)Be(PO_4)OH. Die nahe Strukturverwandtschaft des Väyrynenits mit dem Euklas $AlBe(SiO_4)OH$ wird diskutiert.

Abstract

A new chemical analysis and x-ray single-crystal study are reported for väyrynenite, originally described by Volborth (1954) from Eräjärvi in central Finland. The analysis gave: MnO 34.01, FeO 5.92, CaO 0.53, BeO 13.85, Na_2O 0.20, K_2O 0.04, Al_2O_3 0.40, P_2O_5 39.98, H_2O+ 4.93, H_2O- 0.19, insol. 0.06; total 100.11. X-ray crystallographic data are: monoclinic, space group $P\,2_1/a - C_{2h}^5$; $a = 5.41_1 \pm 0.005$ Å, $b = 14.49 \pm 0.02$, $c = 4.73_0 \pm 0.005$, $\beta = 102° 45' \pm 05'$; cell contents, 4 formula units. The first indexed x-ray powder data and new mineralogical observations on the physical properties are given. The close structural relation between väyrynenite, (Mn,Fe)Be(PO_4)(OH), and euclase, $AlBe(SiO_4)(OH)$, is discussed.

Introduction

The complex granite-pegmatite occurrence at Viitaniemi in the parish of Eräjärvi in central Finland shows a remarkable assemblage of phosphate minerals. There occur here particularly the rare beryllium phosphates, beryllonite $NaBe(PO_4)$, hurlbutite $CaBe_2(PO_4)_2$, herderite

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$CaBe(PO_4)(F,OH)$, and väyrynenite $(Mn,Fe)Be(PO_4)(OH)$, all of which have been described recently in great detail by VOLBORTH (1954a, 1954b, 1954c, 1954d). This paper gives additional mineralogical data and a new chemical analysis for väyrynenite (vī′-rĭ-nĕ-nite) from this same locality. In addition to the phosphate minerals listed by VOLBORTH as occurring at Eräjärvi, eosphorite, fairfieldite, and moraesite have been found and identified by the authors.

The existence of this manganese-iron beryllium phosphate was known to VON KNORRING as early as 1939 when he recognized it as a possible new mineral in several specimens collected by him at that time. In these specimens väyrynenite occurs in the following characteristic associations: 1) pink crystal aggregates up to 5 cm long, resembling rubellite, in a matrix of finely divided greenish-yellow muscovite (gilbertite) with microcline, amblygonite, apatite, and quartz; 2) brownish-pink crystals 1—3 mm long, enclosed in massive pink eosphorite with amblygonite, dark-green tourmaline, topaz, muscovite, cassiterite, and quartz; 3) pale gray crystal aggregates up to 3 cm long, intimately associated with massive pale gray apatite; and 4) partly replacing beryllonite crystals, in wedge-like pockets of quartz with amblygonite, microcline, and muscovite.

X-ray crystallography

A single-crystal x-ray study was made with a euhedral crystal of väyrynenite (about $0.5 \times 0.5 \times 0.75$ mm), mounted at the end of a glass fiber so that the crystallographic c axis was parallel with the fiber length. Zero-level patterns of the $h0l$ and $0kl$ nets as well as first-level patterns of the $h1l$ and $1kl$ nets were taken with a quartz-calibrated Buerger precession camera, using Mo/Zr radiation ($\lambda = 0.7107$ Å) to establish the lattice type and symmetry. These films were measured and corrected for film shrinkage. Systematic extinctions were observed to be of the type $h0l$, with $h \neq 2n$, and $0k0$ with $k \neq 2n$. These criteria led unequivocally to the space group $P2_1/a$—$C_{2h}{}^5$.

Complete x-ray crystallographic data for väyrynenite are summarized in Table 1; they are compared with those originally cited by STRADNER in VOLBORTH (1954d). The value for a obtained in the present study differs considerably from that reported by STRADNER. STRADNER's value is almost twice that we obtained in our study. She does not indicate the method by which her crystallographic data were

Table 1. *Crystallographic data for väyrynenite*

	Present study	STRADNER in VOLBORTH (1954d)
Crystal class	Monoclinic; prismatic $-2/m$	Monoclinic
Cell constants		
a	$5.41_1 \pm 0.005$ Å	10.47 Å
b	14.49 ± 0.02	14.40
c	$4.73_0 \pm 0.005$	4.75
β	$102° 45' \pm 05'$	$102° 49'$
$a : b : c$ (x-ray)	0.3734 : 1 : 0.3264	0.7271 : 1 : 0.3299
Cell contents	4[(Mn,Fe)Be(PO_4)(OH)]	8[(Mn,Fe)Be(PO_4)(OH,F?)]
Cell volume	361.7 Å^3	697.0 Å^3
Space group	$P2_1/a - C_{2h}^5$	—
Spec. grav. (calc.)	3.23 (for Mn:Fe = 85:15)	3.35*
Spec. grav. (obs.)	3.215±0.005 (microbalance) 3.22 (suspension method)	3.183 (VOLBORTH)

* Calculated by the present authors on the basis of the cell data and cell contents cited by the original authors.

derived. Also, there is no mention as to whether all the single-crystal x-ray photographs were made from the same crystal or whether several crystals were used for the various orientations. STRADNER's a value of 10.47 Å is in excellent agreement with the 10.45 Å given for the a value for eosphorite from Newry, Maine by HURLBUT (1950). Pink eosphorite was found by us in close association with väyrynenite which it resembles in habit and color; its identity was established optically and by x-ray powder pattern. There thus exists the possibility that STRADNER may have selected an eosphorite crystal in determining her crystallographic a.

That the a value of STRADNER is in error is borne out further by the fact that the specific gravity calculated by the present authors, using VOLBORTH's formula and STRADNER's cell constants, is far out of line with any of the reported measured values. On the other hand our specific gravity determinations (3.215 by Berman microbalance; 3.22 by suspension method) are in excellent agreement with the calculated value of 3.23 derived from our formula and cell data.

VOLBORTH's powder data for väyrynenite are in good agreement with those obtained in this study (Table 2). His data, however, cannot be indexed in terms of STRADNER's cell, thus further substantiating the fact that one of the cell constants must be in error.

X-ray powder data

X-ray powder patterns were taken with a Debye-Scherrer camera (114.59 mm diameter), using the Straumanis and Wilson techniques, with both Fe/Mn and Cu/Ni radiations ($\lambda = 1.9373$ Å; $\lambda = 1.5418$ Å). The pattern taken in Fe$K\alpha$ radiation (film 8762) was so far superior to

Table 2. *X-ray powder data for väyrynenite,* (Mn,Fe)Be(PO_4)(OH)

Monoclinic, $P2_1/a - C_{2h}^5$

$a = 5.41_1 \pm 0.005$ Å, $b = 14.49 \pm 0.02$, $c = 4.73_0 \pm 0.005$, $\beta = 102° 45' \pm 05'$

Volborth (1954a) *		Present study **				Volborth (1954a) *		Present study **			
Measured (analysis material)		Measured (film 8762)		Calculated		Measured (analysis material)		Measured (film 8762)		Calculated	
I	d_{hkl}	I	d_{hkl}	d_{hkl}	hkl	I	d_{hkl}	I	d_{hkl}	d_{hkl}	hkl
		85	7.251	7.245	020					2.132	151
5	4.93	25	4.960	4.958	110			13 B	2.100	2.100	201
				4.613	001					2.083	$\bar{1}32$
6	4.44	60	4.399	4.396	011					2.082	$\bar{2}41$
		4	4.265	4.266	120					2.082	032
		13	3.890	3.891	021					2.078	211
				3.790	$\bar{1}11$	5	2.05	25 B	2.057	2.058	$\bar{1}61$
				3.625	040			6	2.019	2.017	221
		4	3.560	3.563	130			9	1.964		
10	3.45	100	3.452	3.454	$\bar{1}21$	6	1.94	9	1.944		
		13	3.340	3.336	031			2	1.915		
		13	3.073	3.075	111			3	1.818		
				3.049	$\bar{1}31$	5	1.80	4	1.803		
		6	2.991	2.988	140			4	1.784		
10	2.87	85	2.885	2.887	121	4	1.72	9 B	1.726		
		35	2.851	2.849	041			3	1.691		
8	2.67	42	2.662	2.663	$\bar{1}41$			4	1.670		
		25 B	2.642	2.639	200			3	1.652		
				2.636	131			3	1.630		
				2.596	210			4	1.597		
		18	2.548	2.545	$\bar{2}01$			4	1.584		
				2.541	150	4 D	1.57	9 B	1.570		
				2.508	$\bar{2}11$	3	1.51	9 B	1.524		
		6	2.480	2.479	220			3 B	1.498		
				2.455	051			2	1.475		
1	2.41	18	2.413	2.414	060	1	1.46	3	1.462		
				2.402	$\bar{2}21$			9	1.427		
				2.376	141			3	1.414		
				2.333	$\bar{1}51$			9	1.386		
		6	2.312	2.315	230			3	1.369		
				2.306	002	3	1.35	2	1.345		
		4	2.279	2.280	012			2	1.334		
				2.279	$\bar{1}12$			4	1.316		
5	2.25	13	2.253	2.252	$\bar{2}31$			4	1.299		
		13	2.202	2.200	$\bar{1}22$			Plus additional weak lines.			
				2.198	022						
				2.196	160						
		9	2.140	2.139	061						
				2.133	240						

* D = diffuse. Camera diameter: 56.7 mm. Cu$K\alpha$ radiation, Ni filter. Original spacings converted by present authors from kX to Å units.

** B = broad. Film corrected for shrinkage. Camera diameter: 114.59 mm. Fe$K\alpha$ radiation, Mn filter ($\lambda = 1.9373$ Å). Lower limit 2θ measurable: approximately 6.0° (18.5 Å).

the one taken in Cu$K\alpha$ radiation that it was the film measured. Measurements were made with a Hilger-Watts film-measuring rule with a vernier precision of 0.05 mm. These measurements were corrected for film shrinkage; a shrinkage correction of 1.0025 was applied. The lower limit of 2θ measurable on film 8762 was found to be approximately 6.0° (18.5 Å). Intensities were obtained by visual comparison with a calibrated film strip such that successive step line-exposures are related to each other by a factor of $\sqrt{2}$. X-ray powder data for väyrynenite are given in Table 2 which lists both observed and calculated interplanar spacings. Observed spacings of the present study are compared with those reported by VOLBORTH (1954a); VOLBORTH's original spacings have been converted to Ångström units for the convenience of having both sets of data on the same scale. Interplanar spacings were calculated from the x-ray cell constants down to $d_{hkl} \geq 2.000$ Å. No indexed pattern of väyrynenite previously has been available. The agreement between the observed and calculated spacings is excellent; all lines measured on film 8762 are satisfactorily accounted for.

Morphological data

Five crystals, including the one used in the single-crystal x-ray study, were examined with the two-circle optical goniometer. The crystals were found to be rather poorly developed, each showing no more than seven measurable faces giving fair and excellent signals.

Table 3. *Comparison of morphological data for väyrynenite*

	Present study	VOLBORTH (1954a)
Crystal class	Monoclinic; prismatic $-2/m$	Monoclinic
Elements (from Table 1)		
Axial ratio	$a:b:c = 0.3734:1:0.3264$; $\beta = 102° 45' \pm 05'$	$a:b:c = 0.7271:1:0.3299$; $\beta = 102° 49'$
Projection	$p_0' = 0.8964$, $q_0' = 0.3264$, $x_0' = 0.2263$	$p_0' = 0.4653$, $q_0' = 0.3299$, $x_0' = 0.2275$
Polar	$p_0:q_0:r_0 = 0.8743:0.3184:1$	$p_0:q_0:r_0 = 0.4537:0.3217:1$
Forms observed	c 001	c 001
	b 010	b 010
	m 110	m 110
		113 (?)*
Dominant forms (descending rank)	m, b, c	

* Apparently a misprint for (013) because it lies in zone with (001) and (010) as indicated on VOLBORTH's stereographic projection (Fig. 5, p. 68).

The results were plotted on a gnomonic projection and the forms identified by comparison with the x-ray lattice. The morphological data thus derived are tabulated in Table 3.

Euhedral crystals of väyrynenite are rare. The crystals, rather simple in habit, are short to long prismatic parallel to [001]. The typical habit is shown in Fig. 1. Only three forms were observed: $c\{001\}$, $b\{010\}$, and $m\{110\}$, the last being the dominant form. The prism faces are generally striated vertically, and for that reason gave multiple signals of only fair quality; but these afforded sufficiently accurate measurements for identifying the form. Because of the absence of a general form, it was impossible to determine conclusively from morphological evidence alone whether the crystal class is $2/m$ or m. A test for piezoelectricity by ISIDORE ADLER of the U.S. Geological Survey was made with an instrument of the Giebe-Scheibe type. The absence of any positive reaction for piezoelectricity supports our assumption for the crystal class $2/m$.

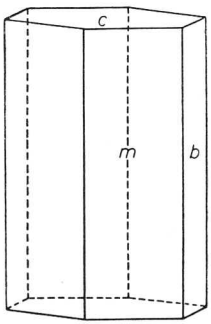


Fig. 1. Typical crystal habit of väyrynenite showing the observed forms: $c\{001\}$, $b\{010\}$, and $m\{110\}$

Averages of measured and calculated angles for väyrynenite are presented below:

Forms	Present study				VOLBORTH (1954a)			
	Measured		Calculated (x-ray cell)		Measured		Calculated (STRADNER's x-ray cell)	
	φ	ϱ	φ	ϱ	φ	ϱ	φ	ϱ
c 001	—	0°00′	—	0°00′	—	0°00′	—	0°00′
b 010	0°00′	90°00′	0°00′	90°00′	0°00′	90°00′	0°00′	90°00′
m 110	69°54′	90°00′	69°59½′	90°00′	54°30′	90°00′	54°30′	90°00′

When the inconsistency between the values for the form $m\{110\}$ was noted, x-ray powder patterns were made of each one of four of the five measured crystals to make certain that the crystals measured were väyrynenite. In each instance a pattern of väyrynenite was obtained. On none of the crystals measured was a form having a φ of 54°30′ observed. Therefore, the perfect agreement between VOLBORTH's measured φ value for $m\{110\}$ and that calculated from STRADNER's x-ray cell constants cannot be accounted for in view of the previous evidence presented for the apparent error in her a value.

Physical and optical data

According to Ridgway's color standards and nomenclature, crystals of väyrynenite are usually pale Congo pink when translucent, and shell pink when transparent; sometimes, pale gull gray and nearly colorless. The streak is white. The cleavage is prismatic with {010} perfect and easy, {100} good but difficult, and {001} fair; the {010} and {100} cleavages were confirmed optically and by Buerger precession photographs. The mineral is brittle and breaks with an uneven fracture. Hardness is 5. The specific gravity determined on the Berman microbalance, using toluene as the immersion liquid, was 3.215 ± 0.005 (an average of eight different measurements); by suspension method in Clerici solution on analysis material, by VON KNORRING, 3.22. The fusibility is 2—3 on von Kobell's scale, producing a dark-brown, magnetic, blebby glass. The mineral is very slowly soluble in cold HCl, HNO_3, and H_2SO_4. It does not fluoresce in either short-wave or long-wave ultraviolet radiation.

Väyrynenite is nearly colorless and non-pleochroic in transmitted light. The perfect cleavage parallel to (010) is readily observed under the microscope. The optical properties are summarized in Table 4. The optical orientation as given by VOLBORTH (1954a; Fig. 5, p. 68) was found to be in error.

Table 4. *Optical data for väyrynenite*

	Present study	VOLBORTH (1954a)
Optic sign	(—)	(—)
Indices		
α	$1.638 \pm 0.001_{(Na)}$	$1.640 \pm 0.001_{(Na)}$
β	$1.658 \pm 0.001_{(Na)}$	$1.662 \pm 0.001_{(Na)}$
γ	$1.664 \pm 0.001_{(Na)}$	$1.667 \pm 0.001_{(Na)}$
$\gamma - \alpha$	0.026	0.027
Optic orientation	$X \wedge c = -31°$	$Z \wedge c \sim 30°$ (?)
	$Y = b$	$Y = b$
Dispersion	$r > v$, moderate	—
$2V_\alpha$ (meas.)	54° 08′	46°
$2V_\alpha$ (calc.)	56° 50′	51°

Chemistry

The analyzed sample was first separated with Clerici solution and further purified by hand picking under the binocular microscope. Samples of approximately 300—400 mg were used for each of the various determinations. The chemical methods mainly used were those recommended by HILLEBRAND and others (1953).

Prior to chemical analysis a sample of väyrynenite was spectrographically analyzed by JANET D. FLETCHER of the U.S. Geological Survey with the resulting percentages:

*X*0.	Mn, Be, P
X.	Fe
.*X*	Al, Ca, Si
.0*X*	Mg, La
.00*X*	Cu, Sr, Y
.000*X*	Ag, Ba, Cr, Yb

Not found: Au, Hg, Mo, W, Ge, Zn, Pb, Bi, As, Sb, Cd, Tl, Co, Ni, V, Sc, Ti, Th, Nb, U, and B.

The chemical analysis by VON KNORRING is given in Table 5. The formula derived from his chemical analysis is $(Mn,Fe)Be(PO_4)(OH)$. Using the specific gravity determination of 3.22, VON KNORRING's

Table 5. *Chemical analyses and cell contents of väyrynenite*

	Theoretical composition (Mn:Fe = 85:15)	Weight per cent		Molecular quotients (von KNORRING's anal.)	Atomic quotients	Experimental cell contents (×704.3/100)	
		VOLBORTH (1954a)	VON KNORRING				
MnO	34.24	30.57	34.01	0.4795	(Mn) 0.4795	3.38	
FeO	6.12	4.59	5.92	0.0824	(Fe) 0.0824	0.58	4.03
CaO		1.82	0.53	0.0095	(Ca) 0.0095	0.07	
BeO	14.21	12.10	13.85	0.5536	(Be) 0.5536	3.90	
Na_2O		1.42	0.20	0.0032	(Na) 0.0064		
K_2O		1.18	0.04	0.0004	(K) 0.0008		
Li_2O		tr					
Al_2O_3		2.45*	0.40	0.0039	(Al) 0.0078		
P_2O_5	40.31	40.36	39.98	0.2816	(P) 0.5632	3.97	
H_2O+	5.12	[5.00]**	4.93	0.2736	(H) 0.5472	3.85	
H_2O-		0.08	0.19		(O) 2.8219	19.87	
F		—***	0.00				
Insol.		0.78	0.06				
Total	100.00	95.35 [100.35]	100.11				

* Trace of Be.

** By difference.

*** The presence of fluorine detected qualitatively.

analysis in Table 5, and our cell dimensions, the experimental molecular weight of the unit cell is 704.3. The calculated cell contents approach closely the formula 4[(Mn,Fe)Be(PO_4)(OH)].

It should be noted that the presence of fluorine is indicated in VOLBORTH's proposed formula for väyrynenite (VOLBORTH, 1954a). In VON KNORRING's chemical determination fluorine was not detected. It is possible, however, that fluorine-bearing varieties of väyrynenite may occur (see herderite). On the other hand, it also is possible that contaminating apatite may account for the presence of fluorine in VOLBORTH's analysis (Table 5).

Structural relation to euclase

VOLBORTH (1954a) suggested the possibility that väyrynenite might be isostructural with herderite, CaBe(PO_4)(F,OH). Although väyrynenite and herderite have the same chemical formula type, a comparison of their x-ray powder patterns and their axial elements

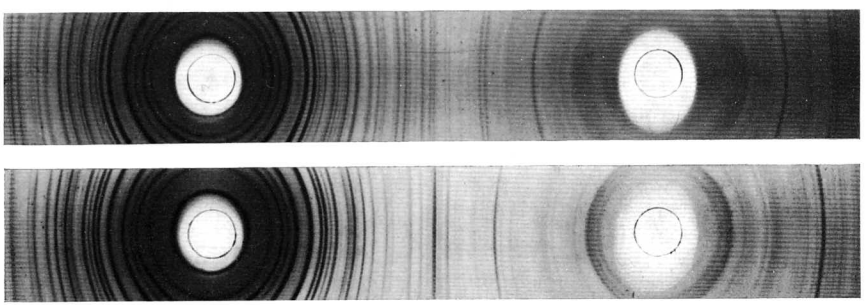
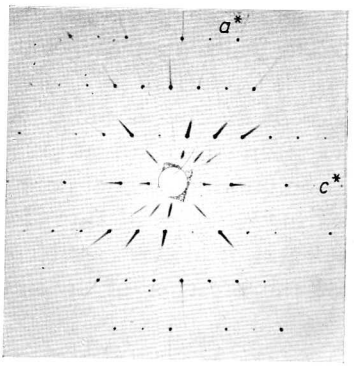


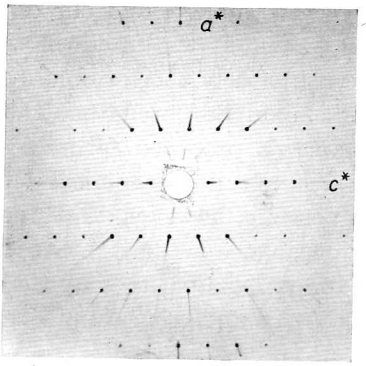
Fig. 2. X-ray powder diffraction patterns of väyrynenite (above) and euclase (below) taken with a 57.3 mm diameter camera using Fe/Mn radiation ($\lambda = 1.9373$ Å)

does not indicate any apparent structural relationship between these two minerals. Later, a comparison of the structure of herderite, described by PAVLOV and BELOV (1957), with that deduced for väyrynenite by MROSE and D. E. APPLEMAN (oral communication) showed that the two minerals have entirely different structures.

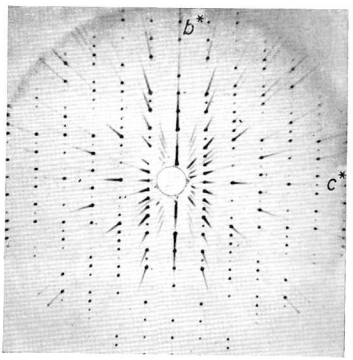
A search of *Crystal data* (DONNAY and NOWACKI, 1954) showed that väyrynenite and euclase, AlBe(SiO_4)(OH), have very close c/b ratios, and that their a/b ratios are relatively close. This, coupled with the fact that both minerals have the same chemical formula type, remarkably similar crystallographic data, and perfect cleavage parallel to (010), strongly suggested that they might be isostructural.



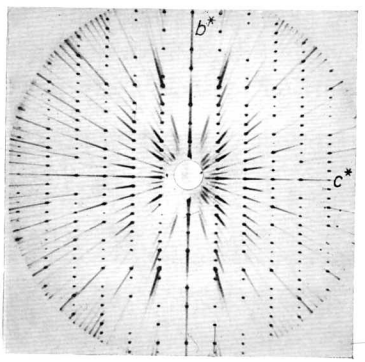
V (010)*



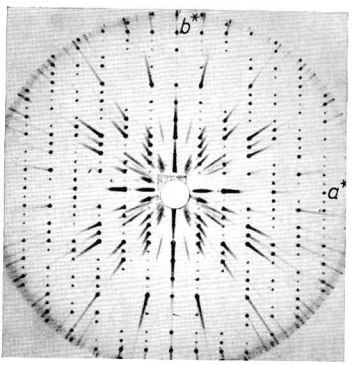
E (010)*



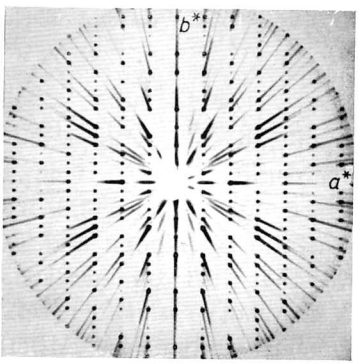
V (100)*



E (100)*



V (001)*



E (001)*

Fig. 3. Precession films of the reciprocal-lattice planes (010)*, (100)*, and (001)* of väyrynenite (V) and euclase (E). Mo/Zr radiation; 50 kV, 18 mA; 20-hour exposures

As with herderite, the x-ray powder pattern of euclase showed no strong structural resemblance to väyrynenite (Fig. 2). Nevertheless, the crystallographic similarities, using the data of BISCOE and WARREN (1933) for comparison, were confirmed by a reinvestigation of euclase by the Buerger precession method. Although the powder patterns of the two minerals appeared to be different, the precession *h*0*l*, *hk*0, and 0*kl* nets of the two minerals were remarkably similar (Fig. 3). In order to elucidate the relation between these two structures, the determination of the structure of väyrynenite and the redetermination and refinement of the euclase structure were undertaken. These two structure determinations have been completed; the results will appear shortly (MROSE and D. E. APPLEMAN, oral comm.).

Crystallographic data for euclase

Single-crystal x-ray studies were made using a small cleavage fragment of euclase from Villa Rica, Minas Geraes, Brazil (USNM R3775). Precession photographs of the *h*0*l*, 0*kl*, and *hk*0 nets, as well as of the 1*kl* and *hk*1 nets, were obtained with a quartz-calibrated Buerger precession camera, using Mo/Zr radiation ($\lambda = 0.7107$ Å). The

Table 6. *Comparison of crystallographic data for väyrynenite and euclase*

	Väyrynenite	Euclase	
	Present study	Present study	BISCOE and WARREN (1933)*
Cell constants			
a	$5.41_1 \pm 0.005$ Å	$4.76_3 \pm 0.005$ Å	4.76 Å
b	14.49 ± 0.02	14.29 ± 0.02	14.27
c	$4.73_0 \pm 0.005$	$4.61_8 \pm 0.005$	4.63
β	102° 45′ ± 05′	100° 15′ ± 05′	100° 16′
$a:b:c$	0.3734:1:0.3264	0.3333:1:0.3232	0.3336:1:0.3244
Cell contents	4[(Mn,Fe)Be(PO$_4$)(OH)]	4[AlBe(SiO$_4$)(OH)]	4[AlBe(SiO$_4$)(OH)]
Cell volume	361.7 Å^3	309.3 Å^3	309.5 Å^3
Space group	$P2_1/a$–C_{2h}^5	$P2_1/a$–C_{2h}^5	$P2_1/a$–C_{2h}^5
Spec. grav. (calc.)	3.23 (for Mn:Fe = 85:15)	3.115	3.113
Spec. grav. (obs.)	3.215 ± 0.005 (microbalance) 3.22 (suspension method)	3.095 ± 0.005 (microbalance)	—

* Original values converted by the present authors to Å units; c and a interchanged so that $c < a$.

Table 7. *X-ray powder data for euclase*, $AlBe(SiO_4)(OH)$

Monoclinic, $P2_1/a - C_{2h}^5$

$a = 4.76_3 \pm 0.005$ A, $b = 14.29 \pm 0.02$, $c = 4.61_8 \pm 0.005$, $\beta = 100° 15' \pm 05'$

McKie (1955) [1]		Present Study [2]				McKie (1955) [1]		Present Study [2]	
Measured		Measured (film 12836) [3]		Calculated		Measured		Measured (film 12836) [3]	
I	d_{hkl}	I	d_{hkl}	d_{hkl}	hkl	I	d_{hkl}	I	d_{hkl}
100	7.2	100	7.146	7.145	020	5	1.754	2	1.748
15	4.55	6	4.547	4.545	001	1	1.716	1	1.720
		4	4.457	4.454	110			1	1.690
		1	4.331	4.331	011	20	1.672	9	1.675
				3.920	120			9	1.664
50	3.85	35	3.836	3.834	021	3	1.650	2	1.647
15	3.60	13	3.576	3.573	040	15	1.624	4	1.621
10	3.53					3	1.565	2	1.562
		3	3.493	3.489	$\bar{1}11$	3	1.539	2	1.539
		4	3.342	3.341	130	10	1.517	1	1.517
10	3.32					15	1.500	2	1.505
		3	3.292	3.288	031			6	1.493
70	3.24					3	1.475	2	1.476
		50	3.219	3.214	$\bar{1}21$	3	1.454	1	1.450
5	3.10					15	1.440	6	1.437
5	2.97	3	2.943	2.941	111			1	<1.424
5	2.88	3	2.871	2.871	$\bar{1}31$	10	1.407	3	1.411
				2.841	140			3	1.401
		4	2.811	2.808	041	5	1.394		
70	2.78	35	2.773	2.771	121			2	1.388
40	2.55	25	2.543	2.543	131	15	1.377	4	1.376
				2.535	$\bar{1}41$	30	1.369	18	1.365
50	2.45	35	2.444	2.440	150	10	1.351	4	1.351
				2.419	051	10	1.339	4	1.337
		2	2.384	2.382	060	10	1.322	3	1.321
15	2.36					15	1.311	8	1.309
		9	2.347	2.344	200			1	<1.293
				2.313	210	5	1.285		
				2.305	002			2	1.284
				2.300	141	5	1.269	2	1.266
		2	2.279	2.276	012	3	1.251	1	1.250
20 B	2.26					3	1.226	1	1.226
		13	2.252	2.253	$\bar{2}01$	5	1.211	2	1.203
				2.238	$\bar{1}51$	3	1.192	1	1.188
				2.227	220	3	1.177	1 B	1.175
				2.225	$\bar{2}11$	15	1.156	4 B	1.155
5	2.18	2	2.182	2.178	$\bar{1}12$	5	1.141	2	1.139
				2.165	022	3	1.117	1	1.120
				2.148	$\bar{2}21$	1	1.102	1	<1.100
5	2.12			2.124	160	1	1.093	1	<1.095
		3	2.111	2.110	061	1	1.078	1	<1.080
				2.107	$\bar{1}22$	1	1.063	1	<1.065
				2.103	230	1	1.058	1	<1.057
15	2.08	9	2.074	2.071	151	1	1.052	1	<1.050
5	2.05			2.051	032	3	1.042	2	1.041
		6	2.040	2.036	$\bar{2}31$	1	1.030	1	<1.028
		2	2.003	2.000	$\bar{1}32$	1	1.023	1	<1.022
30	1.996	18	1.991			1	1.014	1	<1.015
10	1.955	6	1.952			5 B	1.000	2 B	1.000
5	1.924	2	1.924			Plus thirty-eight additional lines ranging from d_{hkl} = 0.990 Å down to d_{hkl} = 0.773 Å, all with I < 6 [4].		Plus additional weak lines.	
30	1.883	18	1.880						
10	1.808	2	1.805						
20	1.786	6	1.790						
		3	1.778						

Explanation of Table 7 see page 287 below

zero-level films were measured. Corrections were made for horizontal and vertical shrinkage. The crystallographic data for euclase are summarized in Table 6 and compared with those obtained for väyrynenite.

The x-ray powder pattern of euclase used for comparison with the pattern of väyrynenite was made from part of the same crystal used in the single-crystal x-ray studies (USNM R3775). The experimental procedure followed in taking and measuring the euclase powder pattern is the same as that described in the x-ray powder data section for väyrynenite. Observed interplanar spacings are compared in Table 7 with those recently published for euclase from Tanganyika (McKie, 1955). A complete set of interplanar spacings was calculated from the present x-ray cell constants; Table 7, column 3 lists all calculated spacings down to $d_{hkl} = 2.000$ Å. This table provides the first available indexed powder data for euclase.

The specific gravity for euclase (USNM R3775) was determined on the Berman microbalance. An average of six different measurements gave a value of 3.095 ± 0.005. This value is in good agreement with the calculated specific gravity of 3.11.

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[1] B = broad, diffuse line. Camera diameter: 9 cm. Cu$K\alpha$ radiation; wavelength not indicated. Lower limit 2θ measurable: 11.0 Å. Not corrected for absorption. Intensities approximate, using the calibrated strip technique.

[2] B = broad. Film corrected for shrinkage. Camera diameter: 114.59 mm. Fe$K\alpha$ radiation, Mn filter ($\lambda = 1.9373$ Å). Lower limit 2θ measurable: approximately 6.0° (18.5 Å).

[3] Specimen from Villa Rica, Minas Geraes, Brazil (USNM R3775).

** The region between $d_{hkl} = 0.910$ Å and $d_{hkl} = 0.821$ Å, inclusive, has particularly indistinct lines.

References

J. BISCOE and B. E. WARREN (1933), The structure of euclase $HBeAlSiO_5$. Z. Kristallogr. **86**, 292—298.

J. D. H. DONNAY and W. NOWACKI (1954), Crystal data. The Geological Society of America, Memoir 60.

W. F. HILLEBRAND, G. E. F. LUNDELL, H. A. BRIGHT and J. I. HOFFMAN (1953), Applied inorganic analysis, John Wiley & Sons, New York.

C. S. HURLBUT, JR. (1950), Childrenite—eosphorite series. Amer. Mineral. **35**, 793—805.

D. MCKIE (1955), Notes on some minerals from Tanganyika. Records of the Geological Survey of Tanganyika **5**, 81—94.

P. V. PAVLOV and N. V. BELOV (1957), The crystalline structure of herderite, datolite, and gadolinite. Proc. Acad. Sciences USSR (Dokl. Akad. Nauk SSSR), Geol. Sci. Section (English Translation), No. 114, 514—545.

R. RIDGWAY (1912), Color standards and color nomenclature, 43pp. Washington, D. C.

A. VOLBORTH (1954a), Phosphatminerale aus dem Lithiumpegmatit von Viitaniemi, Eräjärvi, Zentral-Finnland. Ann. Acad. Sci. Fennicae, Ser. A, **III** Geol. Geogr., No. 39, 1—90.

— (1954b), Väyryneniiti $BeMn(PO_4)(OH,F)$. Geologi (Finland), **6**, 7.

— (1954c), Eine neue, die Phosphatanalyse verkürzende Methode und ihre Anwendung in der Analyse der Beryllium-Phosphate. Z. anorg. allg. Chem. **276**, 159—168.

— (mit Röntgendaten von E. STRADNER) (1954d), Väyrynenit, $BeMn(PO_4)(OH,F)$, ein neues Mineral. Anz. Österreich. Akad. Wiss., Wien, Math.-naturwiss. Kl., **91**, No. 2, 21—23.