THE AMERICAN MINERALOGIST, VOL. 43, SEPTEMBER-OCTOBER, 1958

THE BERYLLIUM CONTENT OF ROSCHERITE FROM THE SAPUCAIA PEGMATITE MINE, MINAS GERAIS, BRAZIL, AND FROM OTHER LOCALITIES*

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ABSTRACT

New spectrographic and chemical data for roscherite from the Sapucaia pegmatite mine, Minas Gerais, Brazil, from the Nevel Quarry at Newry, Maine, and from the type locality at Greifenstein, Saxony, show that roscherite is a beryllium mineral with formula $(Ca, Mn, Fe)_3Be_3(PO_4)_3(OH)_3 \cdot 2H_2O$. The known range in substitution varies from $Ca_{4.45}Mn_{4.45}Fe_{3.1}$ (Greifenstein) to $Ca_{4.0}Mn_{2.7}Fe_{5.3}$ (Newry) and to $Ca_{3.0}Mn_{3.2}Fe_{5.8}$ (Sapucaia pegmatite mine). The unit-cell dimensions derived from x-ray data are $a=15.95$ Å, $b=11.95$ Å, and $c=6.62$ Å; $\beta=94°50'$ (Sapucaia pegmatite mine) and $a=15.88$ Å, $b=11.90$ Å, $c=6.66$ Å, $\beta=94°42'$ (Greifenstein); Z=4. The new $a:c$ ratio is equivalent to the ratio $2a:c$ previously derived from the morphology of the crystals, and the β angle is here refined. Apparently the (110) face from which the $a:b$ ratio originally was determined was misidentified and completely new $a:b$ and $b:c$ ratios are here recorded. The indices of refraction for roscherite from the Sapucaia pegmatite mine are $\alpha=1.636$, $\beta=1.641$, $\gamma=1.651$, biaxial +, dispersion $r>v$, strong.

Roscherite from the Sapucaia pegmatite mine occurs as single crystals, crystal aggregates, and granular crusts in vugs in muscovite. It is associated with faheyite, variscite, frondelite, beryl, and euhedral crystals of quartz.

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 Produção 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. This paper presents a detailed mineralogical description of roscherite, $(Ca,Mn,Fe)_3Be_3(PO_4)_3(OH)_3 \cdot 2H_2O$, from the Sapucaia pegmatite mine and new data are given for roscherite from the type locality at Greifenstein, Saxony and from the Nevel Quarry, Newry, Maine. The beryllium content of roscherite has not been previously recognized. Roscherite was first described as a hydrous calcium iron manganese aluminum phosphate mineral by Slavík (1914). New spectrographic and chemical analyses confirm that beryllium occurs in roscherite as a major constituent and aluminum only in traces.

OCCURRENCE

Roscherite occurs disseminated in the smaller interstices between books of muscovite, as individual measurable crystals, approximately 1 mm. in size, as crystal aggregates, or as fine-grained sericitic-like powdery

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* Publication authorized by the Director, U. S. Geological Survey.

masses. With increasing mineralization, in the larger vugs, the roscherite forms a structureless granular groundmass in which grow euhedral crystals of quartz. Locally, the still open part of the vug may be lined with a fibrous layer of frondelite (Lindberg, 1949), which bends around the roscherite and quartz crystals and is in turn encrusted with an efflorescence of faheyite. Euhedral quartz crystals in the mineralized muscovite are indicative of a high concentration of roscherite and faheyite, and are often encrusted with faheyite. Finely crystalline roscherite intergrown with faheyite imparts a brown color to faheyite. A fibrous matted crust of faheyite, roscherite, and quartz crystals may interleave the thin edges of muscovite books with consequent bending, fraying, and exfoliation of the muscovite (Fig. 1).

In addition to its occurrence in a matrix of muscovite, roscherite also occurs sparsely, admixed with frondelite, in association with multicolored beryl, as brown coloring matter in the cleavage planes in beryl, as a granular crust on beryl, or disseminated in frondelite near the beryl-frondelite contact. In association with beryl, roscherite rarely occurs as a separate phase, but is usually admixed, as a minor constituent of a fine-grained aggregate, with other iron manganese phosphates or with manganoan variscite.

MORPHOLOGICAL AND *X*-RAY CRYSTALLOGRAPHY

Roscherite is monoclinic prismatic. The observed extinctions on single crystal *x*-ray patterns show that the space group is either $C2/c-(C_{2}h^{6})$ or $Cc-(C_{s}^{4})$. The habit of the crystals indicates that the symmetry elements include a 2-fold axis and a mirror plane; the preferred space group for roscherite is therefore $C2/c-(C_{2}h^{6})$.

The orientation of the unit cell selected for crystals of roscherite from the Sapucaia pegmatite mine yields different axial ratios and β angle than those given by Slavík (1914) for roscherite crystals from Greifenstein, Saxony. The new orientation for roscherite follows the convention for monoclinic crystals, $c<a$, with β as nearly orthogonal as possible, and $>90°$ (Table 1). Owing to the scarcity of crystal forms, the crystallographic elements have been calculated from the axial ratios and β angle derived from the *x*-ray study (Table 2).

Crystals of roscherite from the Sapucaia pegmatite mine are characterized by faces of the forms $\{111\}$ and $\{010\}$ well developed in one zone, and faces of the forms $\{100\}$ at an angle to this zone (Fig. 2). On a few crystals faces of the forms $\{102\}$, $\{201\}$, $\{\bar{1}01\}$, $\{\bar{2}01\}$, $\{\bar{3}01\}$, and $\{\bar{1}11\}$ are present as small faces of poor quality (Fig. 3). The crystals are tabular parallel to (100). The crystals differ from those from Greifenstein, Saxony, in that the prism zone is well developed in the latter.

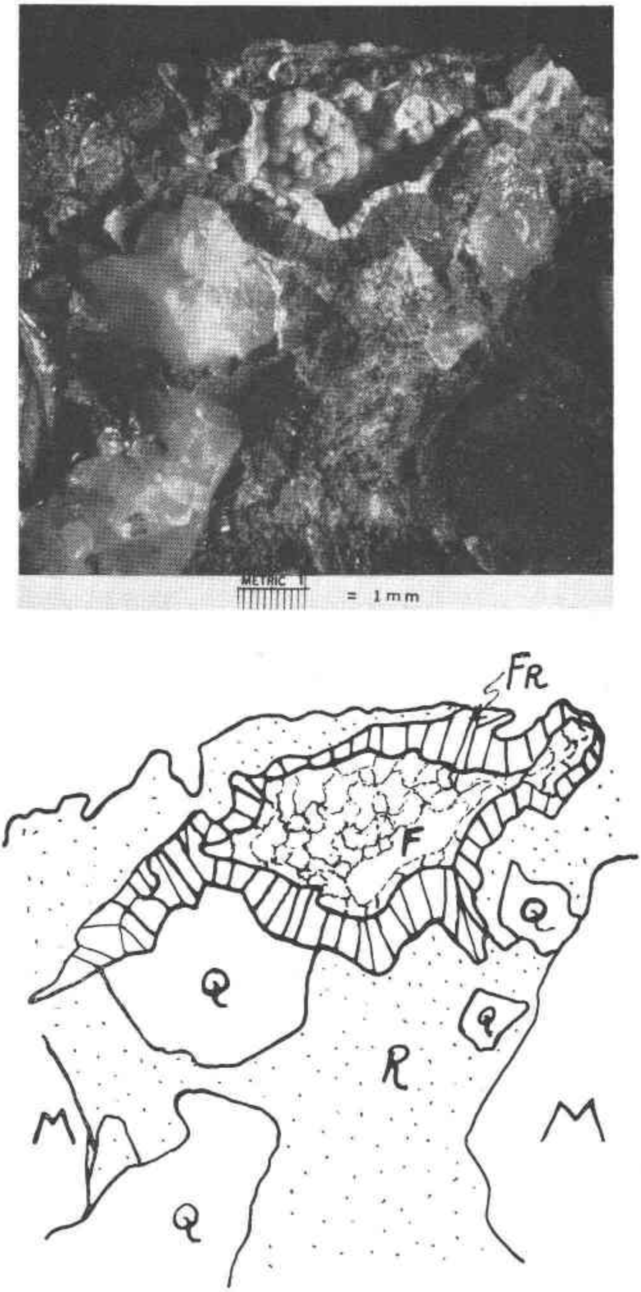

FIG. 1. Photograph showing euhedral quartz crystals (Q) in a matrix of granular roscherite (R) and muscovite (M) in a vug lined with a layer of fibrous frondelite (Fr) and an efflorescence of radiating fibers of faheyite (F).

TABLE 1. *X*-RAY DIFFRACTION DATA
Unit Cell Data

Space group $C2/c-(C_{2h}^6)$

Roscherite Sapucaia pegmatite mine[1]	Roscherite Greifenstein, Saxony[2] U.S.N.M. R6219	Roscherite Nevel Quarry, Newry, Maine[3] Harvard 92220
$a=15.95\pm.06$ Å	$a=15.88\pm.04$ Å	$a=15.89\pm.04$ Å
$b=11.95\pm.04$ Å	$b=11.90\pm.03$ Å	$b=11.90\pm.03$ Å
$c=6.62\pm.04$ Å	$c=6.66\pm.03$ Å	$c=6.59\pm.03$ Å
$\beta=94°50'\pm15'$	$\beta=94°42'\pm15'$	$\beta=94°50'$ (assumed)
volume = 1257 A^3	volume = 1254 A^3	volume = 1242A^3
Sp. gr. = 2.934±0.006 (meas.)	Sp. gr. data from lit. = 2.916[4]	Sp. gr. = 2.936±0.006 (meas.)
Sp. gr. = 2.93± (calc.)	Sp. gr. = 2.90 (calc.)	Sp. gr. = 2.94 (calc.)

X-ray Powder Diffraction Data
Fe/Mn = 1.9373 Å

I	$d_{\text{meas.}}$ (A)	I	$d_{\text{meas.}}$ (Å)	I	$d_{\text{meas.}}$	hkl	$d_{\text{calc.}}$ (Å)
9	9.58	9	9.51	9	9.51	110	9.51
1½	7.95	½	7.97	½	7.90	200	7.92
10	5.96	10	5.95	10	5.95	020	5.95
1	5.61	½	5.59	½	5.63	$11\bar{1}$	5.54
4	4.84	4	4.84	3	4.82	310	4.82
1½	4.42	1½	4.44	1½	4.40	021	4.41
½	3.97	½	3.97	½	3.95	400	3.96
½	3.76		3.77	½	3.76	221	3.76
						311	3.75
1½	3.37	1	3.36	½	3.37	$13\bar{1}$	3.35
						002	3.30
1	3.30	1	3.27	1	3.31	420	3.30
						131	3.29
7	3.18	8	3.17	8	3.17	330	3.17
½	3.15					$11\bar{2}$	3.15
						202	3.13
2B	3.08	2B	3.08	2B	3.06	510	3.06
						112	3.06
2B	2.975	2B	2.979	2B	2.973	040	2.975
				½	2.945	$20\bar{2}$	2.945
½	2.909	½	2.909			$33\bar{1}$	2.914
				½	2.867	511	2.865
						421	2.865
1B	2.839	½	2.831	½	2.825	$31\bar{2}$	2.819
5	2.796	6	2.788	6	2.780	240	2.785
½	2.715	½	2.706			041	2.710
4	2.652	4	2.644	4	2.637	$40\bar{2}$	2.640
						600	2.638
½	2.547	½	2.550			241	2.537
1½	2.428	1½	2.423	1½	2.410	402	2.430
						620	2.414
½	2.386			½	2.376	422	2.414
1	2.365	1	2.356	1	2.350	$53\bar{1}$	2.367
½	2.280	½	2.273			$44\bar{1}$	2.274
2	2.235	1	2.227	1	2.220	332	2.226
						$15\bar{1}$	2.225
						710	2.222
1½	2.176	1	2.181	1	2.196	350	2.170
1	2.060	1	2.062	1	2.061	711	2.054
2	2.040			1	2.033	532	2.042
						351	2.039
2	1.992			1	1.993	060	1.983
		½B	1.981	½	1.981	800	1.979
						602	1.977
1½	1.934			1½	1.922		
1½	1.780	½	1.771	½	1.773		
½	1.756	½	1.746				
½	1.704	½	1.695	½	1.687		
3	1.656	2	1.653	3	1.646		
½	1.619	½	1.608	½	1.608		
½	1.533	½	1.578	½	1.582		
				½	1.573		
½	1.442	½	1.499	½	1.497		
½	1.411	½	1.443				

Debye-Sherrer camera, diameter 114.59 mm.
B = Broad
Lower angle cut-off 11 Å.

[1] Cell dimensions from Weissenberg photographs calibrated for film shrinkage by comparison with an indexed powder photograph; iron radiation, manganese filter, λ = 1.9373 Å.

[2] Cell dimensions from Weissenberg photographs calibrated for film shrinkage by means of a superimposed powder photograph of silver (method of Christ, 1956); copper radiation, nickel filter, λ = 1.5418 Å.

Cell dimensions from indexed powder diffractometer pattern; scale 2 inches = 1° of 2θ; copper radiation, nickel filter, λ = 1.5418 Å.

[4] Data of Slavík (1914).

TABLE 2. MORPHOLOGICAL DATA FOR ROSCHERITE FROM THE SAPUCAIA PEGMATITE MINE

A. Measured data (5 crystals)

Forms:	ϕ_2		ρ_2		Frequency
	Average	Range	Average	Range	
010	—	—	0°00′	—	5
100	0°00′	—	90 54	89°35′–91°40′	8
102	74 30	—	88 38	—	1
201	43 30	42°30′–44°30′	90 25	90 04 –90 46	2
$\bar{1}01$	109 30	—	90 00	—	1
$\bar{2}01$	128 04	—	90 05	—	1
$\bar{3}01$	138 43	—	90 36	—	1
111	63 50	63 50 –64 30	63 44	63 19 –64 15	9
$\bar{1}11$	108 28	—	60 23	—	1

B. Angle table and elements calculated from *x*-ray data[1]

Crystal system: Monoclinic: primatic—$2/m$.
$a:b:c=1.335:1:0.5540$ $\beta=94°50'$ $p_0:q_0:r_0=0.4150:0.5520:1$
$r_2:p_2:q_2=1.812:0.7519:1$ $\mu=85°10'$ $p_0'0.4165,\ q_0'0.5540,\ x_0'0.0846$

Forms:	ϕ	ρ	ϕ_2	$\rho_2=B$	C	A
001	90°00′	4°50′	85°10′	90°00′	—	85°10′
010	0 00	90 00	—	0 00	90°00′	90 00
100	90 00	90 00	0 00	90 00	85 10	0 00
110	36 56	90 00	0 00	36 56	87 06	53 04
102	90 00	16 19	73 41	90 00	11 29	73 41
101	90 00	26 36	63 24	90 00	21 46	63 24
201	90 00	42 31	47 29	90 00	37 41	47 29
$\bar{1}01$	−90 00	18 21	108 21	90 00	23 11	108 21
$\bar{2}01$	−90 00	36 47	126 47	90 00	41 37	126 47
$\bar{3}01$	−90 00	49 20	139 20	90 00	54 10	139 20
111	42 07	36 45	63 25	63 39	33 38	66 20
$\bar{1}11$	−30 55	32 50	108 21	62 17	35 32	106 11
$\bar{3}11$	−64 33	52 11	139 20	70 09	56 36	135 30
$\bar{3}31$	−35 00	63 46	139 20	42 42	66 36	120 58

[1] Includes forms noted on crystals from Greifenstein, Saxony (U.S.N.M. R 6219).

In order to relate the crystallographic directions of the new orientation to the axial directions selected by Slavík in 1914, crystals of roscherite from the type locality (U. S. National Museum No. R6219) have been measured and the forms noted have been related to the new axes selected by *x*-ray methods (Table 3). The crystals of roscherite from Greifenstein, as observed by Lindberg, are characterized by being 6- or

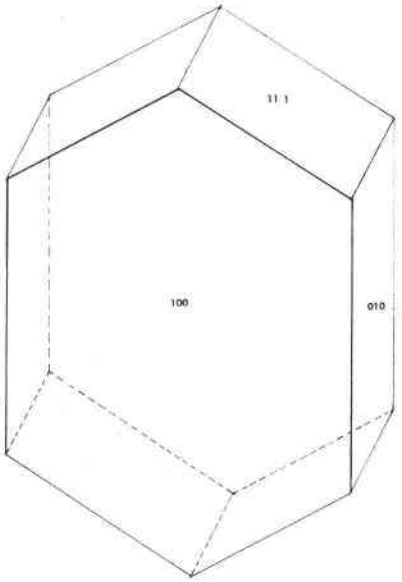

FIG. 2. Typical crystal of roscherite from the Sapucaia pegmatite mine.

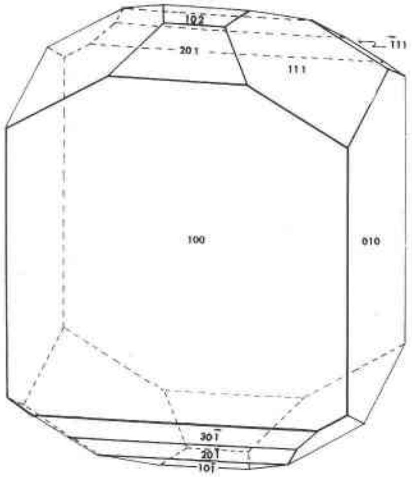

FIG. 3. Crystal of roscherite from the Sapucaia pegmatite mine showing development of the dome faces.

TABLE 3. MORPHOLOGICAL DATA FOR ROSCHERITE FROM GREIFENSTEIN, SAXONY

A. Interfacial angles from literature (5 crystals)[1]

Form	Average	Range	Frequency
a(100) : *c*(001)	80°10′	80°00′ to 80° 20′	2
: *b*(010)	90°27′	87°58′ to 91°24′	9
: *d*(10$\bar{1}$)	52°02′	51°43′ to 52°21′	2
: *m*(110)	42°48′	42°14′ to 43°27′	3
c(001) : *b*(010)	90°07′		1

[1] Data of Slavík, 1914

B. New angle measurements on faces related to axes selected for the unit cell[2]

Form	ϕ		ρ		Frequency	Quality
	Average	Range	Average	Range		
010	0°00′		90°30′	89°40′ to 90°52′	16	G
100	90°55′	89°15′ to 91°40′	90°15′	89°46′ to 90°44′	18	G
110	36°16′	34°38′ to 37°40′	90°37′	89°40′ to 91°23′	38	G
201	90°30′	90°15′ to 90°45′	45°30′	44°00′ to 47°00′	2	P
$\bar{1}01$	−93°00′	−92°30′ to 95°00′	19°33′	19°33′ to 20°45′	3	P
$\bar{2}01$	−91°05′	—	37°05′	—	1	P
$\bar{3}01$	−90°14′	—	48°20′	—	1	P
111	36°45′	—	37°45′	—	1	P
$\bar{1}11$	−31°10′	−31°00′ to −31°20′	33°31′	33°12′ to 33°50′	2	G
$\bar{3}11$	−65°25′	−65°00′ to −66°15′	51°28′	49°10′ to 52°45′	4	F
		ϕ_2		ρ_2		
001	85°00′	84°00′ to 86°00′	90°38′	—	1	P
$\bar{3}31$	138°20′	—	40°14′	—	1	F

[2] Data of Lindberg, roscherite U.S.N.M. no. R6219. The forms {001} and {$\bar{3}31$} were not measured with the crystal oriented [001] but were measurable with the crystal oriented [010].

C. Equivalent Forms

Slavík	Lindberg
1. The *c*-axes parallel with prism zone, cross section 6 or 8 sided; prisms {100}, {010}, and {110}	1. Same
2. Interfacial angle (100) : (110) = 42°48′ Frequency: 3× on 5 crystals	2. Interfacial angle (meas) (100) : (110) = 53°44′ Frequency: 38× on 12 crystals Note: interfacial angle ($\bar{1}00$) : ($\bar{3}01$) = 40°40′ (calc) = 41°17′ (meas) No equivalent intercepts of *b*-axis and the *ac* plane
3. β = 99°50′ measurements from basal reflections imperfect	3. β = 94°42′ from Weissenberg photograph
4. ρ of ($\bar{1}01$) = 37°58′	4. ρ of ($\bar{2}01$) = 37°05′ (meas.) ϕ of (110) = 36°16′ (meas.)
5. a:c = 1.1	5. $\frac{a}{2}$ = 1.2

8 sided in cross section, prismatic parallel to [001], and having the prism zone bounded by {100}, {010}, and {110}.* The shape of the cross section varies with the relative importance of {100}, {010}, and {110}; {100} is usually larger than {110} and {010}, but any of the forms may dominate on individual crystals. Most of the crystals noted by Lindberg are segments of the prism zone, of varying length. Only a few crystals have terminating faces (Fig. 4).

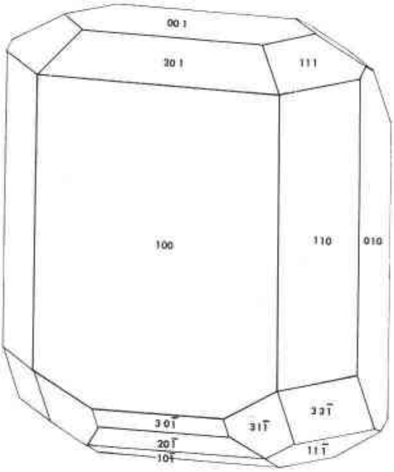

FIG. 4. Crystal of roscherite from Greifenstein, Saxony, showing full development of the terminating faces; typical crystals are usually segments of the prism zone.

The new measurements give different angular relationships and axial ratios than those previously recorded. The interfacial angle (100):(001) given by Slavík as 80°10′ ($\beta = 99°50'$) is considered by Slavík to be an approximate angle measured on crystals with imperfect reflections from the basal pinacoid; in the new measurements the (001) face gives a weak reflection ($\phi_2 = 84°$ to 86° equivalent to $\beta = 96°$ to 94°), but the optical signal is still not of accurately measurable quality. However, the β angle derived from the 0-level Weissenberg pattern of roscherite from Greifenstein is 94°42′±15′. The $(\bar{1}01)$ face of Slavík with a measured ρ of 37°58′ becomes the $(\bar{2}01)$ face of Lindberg with a measured ρ of 37°05′; the new a-axis is double the old a-axis in length.

There are no equivalent intercepts of the b-axis and the ac plane in the two sets of data from which a transformation matrix may be calculated. The calculated ρ_2 value for the {110} form, data of Slavík, suggests an interchange of the a and c axial directions between the two authors. This

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* The same crystal habit for roscherite is described by Slavík (1914) but the interfacial angle (010):(110) of the two authors is different

interchange is not consistent with the interpretation that the $\{\bar{1}01\}$ form of Slavík is equivalent to the $[\bar{2}01]$ form of Lindberg: i.e., both authors observe the presence of a dome face making a ρ angle near 37° with the axis of the prism zone, but no form in any zone, making a ρ_2 angle near 47° with the b-axis was observed by Lindberg during this study.

The $\{110\}$ form observed by Lindberg is characteristic of the prism zone of all the Greifenstein crystals, although no face in any zone making a ρ_2 angle near 37° with the b-axis has been recorded by Slavík. Apparently the fact that the (110) face observed by Lindberg has approximately the same interfacial angle with the (100) face as does the $(\bar{1}01)$ of Slavík has made difficult the correct assignment of faces to zones, the crystallographic elements of Slavík having been calculated from interfacial angles of a given face with $\{100\}$ and from an assumed zone relationship. In the new crystallographic measurements, pyramid faces, observed for the first time on crystals from Greifenstein, establish an interdependency of axes and zones.

The x-ray diffraction data for roscherite are given in Table 1. The unit cell dimensions and β angle for roscherite from the Sapucaia pegmatite mine and from Greifenstein, Saxony, were determined from the Weissenberg patterns of single crystals of roscherite. The unit cell dimensions of roscherite from the Nevel Quarry, Newry, Maine, were determined from an indexed x-ray powder diffractometer pattern, using copper radiation and nickel filter, and a scale of two inches to one degree 2θ, assuming the β angle derived for roscherite from the Sapucaia pegmatite mine.

The x-ray powder d-spacings listed in Table 1 have been obtained using a Debye-Sherrer camera with diameter 114.59 mm., with iron radiation and manganese filter. The resolution in the back reflection range is poor, but film shrinkage is apparently negligible.

PHYSICAL PROPERTIES

Crystals of roscherite from the Sapucaia pegmatite mine are dark brown to reddish-brown in color; those from Greifenstein, Saxony, are olive-green. Roscherite from the Nevel Quarry, Newry, Maine, occurs as light brown radiating fibrous masses. The specific gravities as measured by means of an Adams-Johnston pycnometer of fused silica on the samples used in the analyses are 2.934 ± 0.006 for roscherite from the Sapucaia pegmatite mine and 2.936 ± 0.006 for roscherite from the Nevel Quarry, Newry, Maine; the calculated specific gravities are 2.93 and 2.94, respectively.

The optical properties of crystals of roscherite from the Sapucaia pegmatite mine are: $\alpha = 1.636$, $\beta = 1.641$, $\gamma = 1.651$, $X = b$; biaxial +, dispersion $r>v$ strong; absorption yellow. Roscherite which occurs as a fine-grained replacement of frondelite, admixed with beryl, has higher indices of refraction, with $\gamma = 1.67$ to 1.68.

CHEMICAL COMPOSITION OF ROSCHERITE

Roscherite is a hydrous calcium iron manganese beryllium phosphate with unit cell contents:

$$(Ca,Mn,Fe)_{12}Be_{12}(PO_4)_{12}(OH)_{12} \cdot 8\ H_2O.$$

Calcium, manganese, and iron substitute for each other in varying proportions similar to their mutual substitution in the mineral graftonite (Lindberg, 1950). Roscherite from the type locality at Greifenstein, Saxony, contains $Ca_{4.5}Mn_{4.5}Fe_{3.1}$ atoms per unit cell (Table 4). The present analyses extend the known range of substitution to $Ca_{4.0}Mn_{2.7}Fe_{5.3}$ for roscherite from the Nevel Quarry, Newry, Maine, and to $Ca_{3.0}Mn_{3.2}Fe_{5.8}$ for roscherite from the Sapucaia pegmatite mine. A new mineral name is not here proposed for the iron-rich component since the name roscherite as applied to the type material describes a three component system not predominantly rich in any one end member and in the new analyses the iron cations number barely half the combined calcium, manganese, and iron cations.

The beryllium content of roscherite has not been previously recognized. Spectrographic analyses (Table 5) of roscherite from the type locality (U. S. National Museum R6219) from Newry, Maine, and from the Sapucaia pegmatite mine indicate that beryllium is present in roscherite in quantities approximating the aluminum content previously recorded for roscherite. Standard methods for analyzing the Al_2O_3 content of minerals not known to contain beryllium proceed with the precipitation of the Al_2O_3 in the R_2O_3, followed by deduction from the R_2O_3 of the proper proportions of iron and manganese and calculation of the remaining R_2O_3 as Al_2O_3. Any BeO present in the R_2O_3 would hence be erroneously recorded as Al_2O_3. It may be assumed that this procedure has been followed in the original analysis of roscherite. In Table 4, the analysis of type roscherite by Preis (Slavík, 1914) is recalculated with BeO substituted for Al_2O_3. This substitution is consistent with the spectrographic data of Table 5 and with the new chemical analyses of roscherite (Table 4). The very small quantity of aluminum found in the spectrographic analyses of roscherite from Newry, Maine, and from the Sapucaia pegmatite mine is thought to be associated with the insoluble residues found in the chemical analyses,* as no Al_2O_3 was found collected with

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* Albite occurs admixed with roscherite from the Nevel Quarry, Newry, Maine, and muscovite occurs admixed with roscherite from the Sapucaia pegmatite mine.

TABLE 4. CHEMICAL COMPOSITION OF ROSCHERITE

Roscherite from Greifenstein, Ehrenfriedersdorf, Saxony

	Theoretical[1]	Analysis recalculated[2] to 100% without insoluble	Analysis[3] recalculated with BeO substituted for Al_2O_3	Ratios	Metals ions[4] +H per unit cell
CaO	11.39	11.48	11.48	.2047	4.6
MnO	14.41	14.47	14.47	.2040	4.6
FeO	10.16	10.13	10.13	.1410	3.2
Fe_2O_3					
BeO	13.69		13.74	.5494	12.3
Al_2O_3		13.74			
P_2O_5	38.85	38.01	38.01	.2678	12.0
H_2O	11.50	12.17	12.17	.6755	30.2
Insol.					
Total	100.00	100.00	100.00		
Sp. gr.		2.92[2]			

Roscherite from Nevel Quarry, Newry, Maine (Harvard 92220)

	Theoretical[5]	Analysis[6]	Analysis recalculated to 100% without insoluble	Ratios	Metal Ions +H[4] per unit cell
CaO	10.19	9.95	10.11	.1803	4.0
MnO	8.70	8.52	8.66	.1221	2.7
FeO	17.30	16.22	16.49	.2295	5.05 } 5.3
Fe_2O_3		0.89	0.90	.0056	.25 }
BeO	13.64	12.80	13.01	.5202	11.4
Al_2O_3					
P_2O_5	38.71	38.10	38.74	.2729	12.0
H_2O	11.46	11.89	12.09	.6711	29.5
Insol.		1.25			
Total	100.00	99.62	100.00		
Sp. gr.		2.936±0.006			

(*Continued on opposite page*)

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[1] Theoretical calculated from $Ca_{4.45}Mn_{4.45}Fe_{3.1}Be_{12}(PO_4)_{12}(OH)_{12}\cdot 8H_2O$.

[2] Preis analysis in Slavík (1914).

[3] Spectrographic analysis shows that Be, not Al, is a major constituent of roscherite.

[4] Metal ions+H calculated on the basis of $12PO_4$ per unit cell.

[5] Theoretical calculated from $Ca_{4.0}Mn_{2.7}Fe_{5.3}Be_{12}(PO_4)_{12}(OH)_{12}\cdot 8H_2O$.

TABLE 4 (*continued*)

Roscherite from Sapucaia pegmatite mine, Minas Gerais, Brazil

	Theoretical[7]	Analysis[6]	Analysis recalculated to 100% without insoluble	Ratios	Metal Ions[4] +H per unit cell
CaO	7.59	7.60	7.68	.1369	3.1
MnO	10.24	10.04	10.14	.1430	3.2
FeO	18.80	6.26	6.32	.0880	2.0
Fe_2O_3		13.36	13.49	.0845	3.8
BeO	13.54	12.58	12.71	.0582	11.4
Al_2O_3					
P_2O_5	38.45	37.60	37.98	.2675	12.0
H_2O	11.38	11.56	11.68	.6483	29.1
Insol.		0.80			
Total	100.00	99.80	100.00		
Sp. gr.		2.934			

[6] M. L. Lindberg, analyst.

[7] Theoretical calculated from $Ca_{3.0}Mn_3 \cdot 2Fe_{5.8}Be_{12}(PO_4)_{12}(OH)_{12} \cdot 8H_2O$.

the BeO precipitates from the acid soluble portions of either sample.*

In each of the analyses presented in Table 4 the theoretical analyses assume the ratios of Ca:Mn:Fe reported for the chemical analyses from the same locality. The metal ions and H are calculated on the basis of setting the PO_4 content exactly equal to 12. The measured number of H atoms per unit cell in the three analyses is 30.2, 29.5, and 29.0. The theoretical number of H atoms per unit cell is assumed to be 28. Twelve hydroxyls are required to balance the valencies, if all the iron is divalent. The space group requirement that the number of equivalent positions be divisible by 4 suggests a water content of 8 or 12 molecules per unit cell, corresponding to a total of 28 or 36 H per unit cell. The measured number of H per unit cell, and the molecular weight calculated from the *x*-ray data and specific gravity, are in closer agreement with 28 H per unit cell than with 36 H per unit cell. Similarly, the theoretical quantity of beryllium present is assumed to be 12 cations per unit cell, since the number of equivalent positions per unit cell must be divisible by 4.

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* The optimum pH for the precipitation of $Be(OH)_2$ is slightly higher than that for the precipitation of $Al(OH)_3$ which then may result in incomplete precipitation of $Al(OH)_3$ together with $Be(OH)_2$. The aluminum correction on the ignited BeO precipitate was determined by the fluorometric method of Weissler and White (1946) which method would have detected 0.01% Al_2O_3.

TABLE 5. SEMIQUANTITATIVE SPECTROGRAPHIC EXAMINATION OF ROSCHERITE*

	1	3	4	4
Si	0.3%	0.3%	0.03%	0.01%
Al	0.3	0.3	0.3	0.1
Fe	M	M	10.0	10.0
Mg	0.1	0.1	0.3	0.3
Ca	1.0	3.0	3.0	3.0
Na	0.0	0.03	0.1	0.1
P	M	M	M	M
Mn	3.0	3.0	3.0	3.0
Ba	0.01	0.03	0.0003	0.01
Be	3.0	3.0	3.0	3.0
F	nd	nd	nd	nd
Sr	0.0	0.0	0.01	0.003
Zn	0.3	0.0	0.0	0.1
Zr	0.0	0.0	0.0	0.003
Cu	0.0	0.0003	0.0	0.0

1. Roscherite from the Sapucaia pegmatite mine, Minas Gerais, Brazil; analysis on a 2 mg. sample of purified crystals, sample 9 R, TWS-3016.
2. Roscherite from Greifenstein, Saxony (U. S. National Museum R6219); analysis on a 2.5 mg. sample, TWS-3082.
3. Roscherite from the Nevel Quarry, Newry, Maine (Harvard No. 92220); analysis on a 10 mg. sample, TWS-3149.
4. Roscherite from the Nevel Quarry, Newry, Maine, specimen courtesy of Mary Mrose; analysis on a 5 mg. sample, TWS-3149.

* Analyst, Katherine V. Hazel, U. S. Geological Survey. Figures are reported to the nearest number in the series 10, 3, 1, 0.3, etc., in per cent; M, major, greater than 10%. For comparison with chemical analyses, figures must be converted to oxides; for example, Be reported as 3.0% corresponds to a Be content varying between 2 and 7.5% or a BeO content varying between 6 and 21%. nd = not detected.

At the Sapucaia pegmatite mine the iron contained in the roscherite is in part oxidized, with concomitant adjustment of the hydroxyl-water ratio in order to balance the valencies. Roscherite probably derives its iron and manganese content from frondelite, which, in part, it replaces, and varies in composition in association with that mineral.* The analysis (and optical properties) are considered representative of the occurrence of roscherite as crystals and as granular crusts in a zone intermediate to a green fibrous layer of frondelite and to an efflorescent coating of faheyite in vugs in muscovite. Indices of refraction of roscherite which replaces

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* Green frondelite in association with roscherite in muscovite contains 6.70% FeO, 5.54% MnO, and 41.93% Fe_2O_3; brown frondelite (type) contains 7.74% MnO, 1.75% Mn_2O_3, and 48.85% Fe_2O_3.

brown frondelite associated with multi-colored beryl are higher and indicate a range in iron content or in state of oxidation of the iron.

Roscherite, which contains only divalent metals, is easily soluble in dilute HCl, HNO_3 and H_2SO_4. With increasing oxidation of the iron the solubility in HCl remains the same, but in HNO_3 and in H_2SO_4 the solubility decreases.

MINERAL RELATIONSHIPS

The crystal chemistry of beryllium phosphate minerals is not well understood. Many minerals now known to be beryllium minerals have been first described as aluminum minerals, due to the similarity in behavior of beryllium and aluminum ions in solution, and their co-precipitation of hydroxyl ions in nearly neutral solutions.

The beryllium content of roscherite is noted for the first time. Two new beryllium phosphate minerals, faheyite (Lindberg and Murata, 1953) and moraesite (Lindberg, Pecora, and Barbosa, 1953) have been first described from the Sapucaia pegmatite mine. One of these, moraesite, occurs as fine fibers in association with roscherite, at Greifenstein, Saxony (U. S. National Museum R6219). Childrenite, an aluminum bearing phosphate, occurs in association with roscherite at both localities and crystals of variscite grow in the same vugs as crystals of roscherite and fibers of faheyite at the Sapucaia pegmatite mine. It appears significant that aluminum and beryllium ions are effectively separated in nature into individual hydrous phosphate mineral species which co-exist in the same vug, when under laboratory conditions aluminum and beryllium ions coprecipitate. The amphoteric character of both aluminum and beryllium ions and the effective complete precipitation of beryllium from solutions slightly more basic than solutions from which aluminum quantitatively separates suggests that a changing pH in nearly neutral solutions may be a factor in the formation of these minerals.

Roscherite differs chemically from faheyite in that faheyite contains no calcium, less beryllium, more water, and no divalent iron.

ACKNOWLEDGMENTS

The author is indebted to colleagues in the U. S. Geological Survey, particularly to William T. Pecora for providing the specimens containing the roscherite, to Katherine V. Hazel for the spectrographic analyses, and to Daphne Ross and Betsy Levin for *x*-ray powder photographs. The roscherite from the type locality at Greifenstein, Saxony was obtained through the courtesy of Dr. George Switzer of the U. S. National Museum; roscherite from the Nevel Quarry, Newry, Maine through the courtesy of Prof. Clifford Frondel of Harvard University.

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Manuscript received January 24, 1958