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Kosnarite, $KZr_2(PO_4)_3$, a new mineral from Mount Mica and Black Mountain, Oxford County, Maine

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ABSTRACT

Kosnarite, ideally $KZr_2(PO_4)_3$, has been identified as part of a late-stage, secondary phosphate mineral assemblage from the Mount Mica pegmatite at Paris, and from the Black Mountain pegmatite, Rumford, Oxford County, Maine.

Kosnarite from Mount Mica occurs as pseudocubic rhombohedral crystals, as much as 0.9 mm in maximum dimension, that display the dominant {102} form. Color ranges from pale blue to blue-green to nearly colorless. The mineral has a white streak, is transparent, has a vitreous luster, and is nonfluorescent in ultraviolet light. It has a hardness of 4.5, is brittle with a conchoidal fracture, and has perfect {102} cleavage. Measured and calculated densities are D_m 3.194(2) and D_c 3.206. Optically, this mineral is characterized as uniaxial (+), with refractive indices of $N_\omega = 1.656(2)$ and $N_\epsilon = 1.682(2)$ and is nonpleochroic. Twinning was not observed.

The mineral is hexagonal (rhombohedral), space group $R\bar{3}c$, with $a = 8.687(2)$, $c = 23.877(7)$ Å, $V = 1560.4(8)$ Å^3, $Z = 6$. The six strongest diffraction lines [d(Å), hkl, I/I_o] from the Mount Mica occurrence are 6.41, 012, 50; 4.679, 104, 50; 4.329, 110, 100; 3.806, 113, 90; 2.928, 116, 90; 2.502, 300, 50. Mean analytical results are Na_2O 1.4, K_2O 8.7, Rb_2O 0.25, FeO 0.2, MnO 1.0, ZrO_2 44.5, HfO_2 0.5, P_2O_5 43.3, F 0.20, sum 100.05, less O for F 0.08, total 99.97 wt%. The empirical formula (based on O + F = 12) is $(K_{0.93}Na_{0.08}Rb_{0.01})_{\Sigma 1.02}(Zr_{1.81}Na_{0.15}Mn_{0.07}Fe_{0.01}Hf_{0.01})_{\Sigma 2.05}P_{3.06}(O_{11.95}F_{0.05})_{\Sigma 12.00}$. Kosnarite from Black Mountain is almost pure $KZr_2(PO_4)_3$ with only trace amounts of Hf, Mn, Na, and Rb. The mineral is one of three known alkali zirconium phosphates; the others are gainesite and the Cs analogue of gainesite.

The name is for Richard A. Kosnar of Black Hawk, Colorado.

INTRODUCTION

In 1991, Vandall T. King of Rochester, New York, sent a micromount specimen of a rhombohedral, light sky blue mineral that he thought was possibly a member of the crandallite group to M.E.B. This specimen, and approximately 25 others, were collected at the Mount Mica granite pegmatite in 1989 by Gene T. Bearss of Sanford, Maine. At about the same time, King sent to E.E.F. a micromount specimen of an aggregate of three white, doubly terminated ditetragonal pyramids that he suspected might be gainesite. The latter specimen was also collected by Bearss from the same boulder in the Mount Mica quarry. Detailed studies have shown the blue mineral to be the first natural occurrence of $KZr_2(PO_4)_3$ and the white mineral to be the Cs analogue of gainesite; thus both are new mineral species.

Subsequent to completing the studies of kosnarite from Mount Mica, additional samples of suspected crandallite group minerals from Maine pegmatites were analyzed quantitatively. One of them, a sample from a pegmatite exposed in the Black Mountain Quarry on Black Mountain near Rumford, Maine, was found to contain kosnarite of nearly end-member composition. The extremely small amount of this latter material has precluded determination of its unit-cell, optical, and other mineralogical data.

OCCURRENCE

The mineral occurs at the Mount Mica granitic pegmatite, one mile northeast of Paris, Oxford County, Maine. The Mount Mica pegmatite, first discovered in 1820 (Hamlin, 1895), is well known for its production of elbaite. Kosnarite occurs in a boulder approximately 1 × 1.3 × 1.7 m in size, which was mined in 1978–1979. Gene T. Bearss collected mineral samples from the boulder in the summer of 1989 and later that year hand de-

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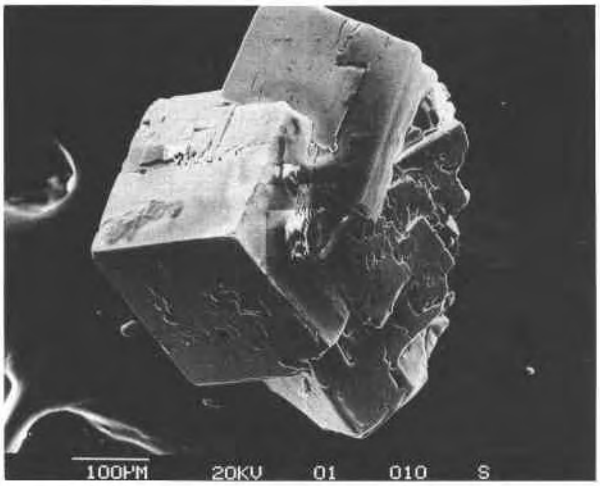

Fig. 1. SEM photomicrograph of kosnarite crystals from Mount Mica, Oxford County, Maine. Scale bar is 100 μm.

Table 1. Electron-microprobe analyses of kosnarite from Mount Mica and Black Mountain, Oxford County, Maine (in wt%)

	Mount Mica		Black Mountain	
Oxide	Mean	Range	Mean	Range
P_2O_5	43.3	43.2–43.7	42.2	40.7–44.0
ZrO_2	44.5	43.9–45.1	47.9	46.7–49.4
HfO_2	0.5	0.4–0.6	0.9	0.5–1.4
MnO	1.0	0.7–1.3	<0.1	—
FeO	0.2	0.2–0.3	<0.1	—
K_2O	8.7	8.6–8.8	9.25	8.8–9.6
Na_2O	1.4	1.4–1.7	<0.1	—
Rb_2O	0.25	0.2–0.3	0.2	0.16–0.27
F^-	0.20	0.2–0.3	0.2	0.20–0.30
Total	100.05		100.65	
O = F	0.08		0.08	
Total	99.97		100.57	

Note: Ideal $KZr_2(PO_4)_3$ requires 9.30 wt% K_2O, 42.04 wt% P_2O_5, and 48.66 wt% ZrO_2. Mean values: Mount Mica (eight analyses) and Black Mountain (11 analyses). Empirical formulae (on the basis of 12(O + F): Mount Mica: $(K_{0.93}Na_{0.08}Rb_{0.01})_{\Sigma 1.02}(Zr_{1.81}Na_{0.15}Mn_{0.07}Fe_{0.01}Hf_{0.01})_{\Sigma 2.05}P_{3.06}(O_{11.95}F_{0.05})_{\Sigma 12.00}$; Black Mountain: $(K_{0.99}Rb_{0.01})_{\Sigma 1.00}(Zr_{1.96}Hf_{0.02})_{\Sigma 1.98}P_{3.00}(O_{11.95}F_{0.05})_{\Sigma 12.00}$.

livered some specimens of kosnarite to Harvard University for identification. At about the same time, specimens of kosnarite and the Cs analogue of gainesite, which were suspected to be phosphate minerals because of their associations, were provided by Bearss to Vandall T. King. Groundmass minerals of the boulder are albite, quartz, almandine spessartine, muscovite, siderite, and apatite. Embedded in these groundmass minerals are blue elbaite, lepidolite, beryl, montebrasite, rhodochrosite, cassiterite, manganocolumbite, uraninite, and löllingite. Within the mass of the boulder were small vugs (1–5 mm across) developed in siderite and massive apatite. These vugs contained euhedral crystals of siderite, eosphorite, fluorapatite, moraesite, quartz, and kosnarite. Pseudocubic crystals of kosnarite are as much as 0.9 mm in maximum dimension. Other vugs (2–3 mm across) contained euhedral crystals of albite, quartz, siderite, eosphorite, and roscherite.

Another new mineral species, the Cs analogue of gainesite, was found in the vugs associated with quartz, siderite, and albite. Both kosnarite and the Cs analogue of gainesite formed late in the paragenesis as late-stage hydrothermal alteration products of earlier formed pegmatite minerals.

Kosnarite from Black Mountain, Oxford County, Maine, also occurs in a zoned granitic pegmatite and is associated with quartz, albite, rubellite, and lepidolite. Primary accessory minerals in the pegmatite include garnet, manganocolumbite manganotantalite, beryl, cassiterite, and small amounts of apatite, triphylite, zircon, and pyrite (Brown and Wise, 1991). The mineral assemblages of both pegmatites (Mount Mica and Black Mountain) are treated in further detail in King and Foord (1993). Details of the geological and age relationships are given in King (1993).

A third occurrence of kosnarite has been found in a granitic pegmatite vein at Wycheproof, in northern Victoria, Australia (Birch, 1992 personal communication). The mineral occurs as 0.5-mm rhombohedral crystals, close to the end-member composition, in a single miarolitic cavity. Gainesite and several unknowns also occur in the same vein.

The species and name were approved by the Commission on New Minerals and Mineral Names (CNMMN) of the IMA. Kosnarite type material has been deposited with the U.S. National Museum under nos. NMNH 170369 and NMNH 170370. The Mineralogical Museum at Harvard University also has samples of kosnarite, provided by Bearss in 1989.

Analytical methods and instrumentation

Because of a scarcity of material, X-ray powder diffraction data were obtained using a Gandolfi camera 114.6 mm in diameter. Density was determined by sink-float methods in a methylene iodide and acetone mixture. Chemical composition was determined with an ARL-SEMQ electron microprobe using an Opus microprobe automation system (Meeker and Quick, 1991) with online CITZAF correction procedures (Armstrong, 1988) at the U.S. Geological Survey in Denver, Colorado. Standards used were (Na) Amelia albite, (P) Wilberforce fluorapatite, (K) Itrongay orthoclase, Rb (synthetic RbCl and Rb-bearing pollucite), (Zr) natural zircon and synthetic ZrO_2, (Fe) olivine, (Mn) willemite, (Hf) zircon, (Cs) pollucite, and (F) fluorite. Al, Si, and Ti were looked for and not detected. Emission spectrographic analysis was done using a Jarrell-Ash 3.2-m spectrograph with a laser energy source.

Results

An initial laser emission spectrographic semiquantitative analysis of kosnarite from Mount Mica showed the

TABLE 2. Indexed X-ray powder diffraction data for kosnarite from Mount Mica, Maine

Mount Mica				Synthetic PDF 35-756		Calculated pattern PDF 25-1206	
d_{meas}	d_{calc}	*hkl*	I/I_o	d_{meas}	I/I_o	d_{meas}	I/I_o
6.41	6.36	012	50	6.393	11	6.378	33
4.679	4.676	104	50	4.695	26	6.682	48
4.329	4.343	110	100	4.363	65	4.355	100
3.806	3.813	113	90	3.828	61	3.821	89
3.167	3.182	204	40	3.194	37	3.189	39
2.928	2.934	116	90	2.944	100	2.939	98
2.816	2.823	211	5	2.835	8	2.831	8
2.561	2.567	214	5	2.576	8	2.573	7
2.502	2.507	300	50	2.517	33	2.514	30
2.279	2.276	1,0,10	3	2.283	3	—	—
2.263	2.264	119	3	2.271	7	2.267	4
2.169	2.172	220	10	2.180	5	2.177	5
2.120	2.122	306	10	2.129	16	2.126	13
2.054	2.059 2.056	218 312	8	2.066	11	2.062	8
2.013	2.016	2,0,10	8	2.022	8	2.018	6
1.971	1.970	134	8	1.977	8	1.974	7
1.903	1.906	226	45	1.913	30	1.910	25
1.826	1.829	2,1,10	40	1.834	19	1.831	16
1.784	1.780	137	5	1.786	4	1.784	3
1.711	1.710	318	15	1.716	5	1.713	4
1.660	1.658	324	15	1.664	8	1.662	7
1.641	1.641	410	35	1.648	19	1.646	15
1.605	1.607	2,2,10	3	—	—	—	—
1.570	1.571	1,3,10	8	1.576	10	1.574	9
1.552	1.553	2,0,14	13	1.558	9	1.555	7
1.518	1.518	416	25	1.523	12	1.521	11
1.477	1.477	4,0,10	8	1.482	3	1.480	3
1.464	1.463 1.463	1,0,16 1,2,14	5	1.467	1	1.464	7
1.447	1.448	330	8	1.453	5	1.452	4
1.400	1.399	3,2,10	3	1.404	2	1.401	2
1.386	1.387 1.386	2,0,16 335	3	1.391	1	1.387	2
1.362	1.361	336	5	1.366	2	1.364	3
1.320	1.320 1.318	3,1,14 514	35	1.325 1.323	7 8	1.321	7
1.256	1.256	517	25	1.261	4	1.257	4
1.214	1.214 1.213	3,1,16 3,2,14	3	—	—	1.215	3

Note: Plus nine more lines to 0.982 Å. Data obtained using a Gandolfi camera 114.6 mm in diameter, utilizing Cu*Kα* (1.54178 Å) radiation, 40 kV, 30 Ma, 2-h exposure time. About nine very weak reflections from the calculated pattern of the synthetic compound were also seen on the film of the natural material but were not used in the final refinement.

presence of major amounts of Zr, P, K, and minor amounts of Mn. Approximately 0.1 wt% Ca and 0.2 wt% Zn were also detected but were later found to be contaminants. SEM-EDS analyses confirmed these results. X-ray powder diffraction data were found to match closely synthetic $KZr_2(PO_4)_3$ (Sljukic et al., 1969; Majling et al. 1979; Morris et al., 1985). The structure of the synthetic compound was determined by Sljukic et al. (1969).

Kosnarite from Mount Mica and Black Mountain occurs as pseudocubic rhombohedral crystals as much as 0.9 mm in maximum dimension with the predominant {102} form (Fig. 1). Color ranges from pale blue to blue-green to nearly colorless. The intensity of color correlates well with the content of Mn and Fe (Table 1). The mineral has a white streak, is transparent, and has a vitreous luster. Its fluorescence is indiscernible in LW and SW ultraviolet light. It has a hardness of 4.5 and is brittle, with conchoidal fracture and a perfect {102} cleavage. Measured and calculated densities are D_m 3.194(2) and D_c 3.206. Optical properties are uniaxial (+), N_ω 1.656(2) and N_ϵ 1.682(2), and nonpleochroic. Twinning was not observed.

TABLE 3. Comparison of unit-cell data and density between synthetic and natural kosnarite

		Kosnarite	PDF 25-1206 synth. $KZr_2(PO_4)_3$	PDF 35-756 synth. $KZr_2(PO_4)_3$
Unit-cell dimensions	*a*	8.687 Å	8.710 Å	8.719 Å
	c	23.877 Å	23.890 Å	23.944 Å
	V	1560.45 Å³	1569.58 Å³	1576.42 Å³
Density	D_m	3.194	—	—
	D_c	3.206	3.214	3.201

The mineral is hexagonal (rhombohedral), space group $R\bar{3}c$, with $a = 8.687(2)$, $c = 23.877(7)$ Å, $V = 1560.4(8)$ Å³, $Z = 6$. Indexed X-ray powder diffraction data for both natural and synthetic kosnarite, as well as a calculated pattern derived from the crystal structure (Sljukic et al., 1969), are given in Table 2.

Mean electron microprobe analytical results for kosnarite from Mount Mica are given in Table 2: Na_2O 1.4, K_2O 8.7, Rb_2O 0.25, MnO 1.0, FeO 0.2, ZrO_2 44.5, HfO_2 0.5, P_2O_5 43.3, F 0.20, sum 100.05, or less O for F 0.08, total 99.97 wt%. Cs, Si, Al, and Ti were also looked for and not detected. The empirical formula (based on O + F = 12) is $(K_{0.93}Na_{0.08}Rb_{0.01})_{\Sigma 1.02}(Zr_{1.81}Na_{0.15}Mn_{0.07}Fe_{0.01}Hf_{0.01})_{\Sigma 2.05}P_{3.06}(O_{11.95}F_{0.05})_{\Sigma 12.00}$. Electron microprobe analysis (Table 1) of colorless kosnarite from a granitic pegmatite on Black Mountain is nearly of end-member composition, containing only minor or trace amounts of Hf, Mn, Na, and Rb.

Because of the limited amount of natural material from both occurrences and because the structure of the synthetic equivalent compound had been determined previously (Sljukic et al., 1969), CO_2 and H_2O were not determined. For these reasons, infrared spectra and DTA and TGA curves also were not determined.

DISCUSSION AND CONCLUSIONS

Kosnarite is one of only three known alkali zirconium phosphates; the other two are gainesite (Moore et al., 1983) and the Cs analogue of gainesite.

Unit-cell parameters for synthetic pure $KZr_2(PO_4)_3$ (Sljukic et al., 1969) are slightly larger than those for natural material from Mount Mica (Table 3). The small decrease in density, cell dimensions, and unit-cell volume of kosnarite relative to the pure synthetic compound is probably due to substitution of Na for K.

The fair compatibility ($1-K_P/K_C$) of −0.064 in kosnarite is probably due to imperfectly known *K* values (Mandarino, 1981). The combination of alkali metals and Zr in a phosphate may require different constants, since all three alkali zirconium phosphate minerals have only fair to poor compatibility [gainesite (−0.101, poor) and the Cs analogue of gainesite (−0.098, poor)].

Both kosnarite and the Cs analogue of gainesite are late hydrothermal minerals and may have formed as a result of the breakdown of zircon and beryl. Etched beryl and etched zircon are known to occur at Mount Mica.

The mineral is named kosnarite in honor of Richard A. Kosnar (1946–) of Black Hawk, Colorado, in honor and recognition of his more than 25 years of study of pegmatite and other mineral species and for his encouragement of interaction between professional and amateur mineralogists.

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References cited

Armstrong, J.T. (1988) Analysis of silicate and oxide materials: Comparison of monte carlo, ZAF, and $\phi(\rho Z)$ procedures. In D.E. Newberry, Ed., Microbeam analysis—1988, p. 239–246. San Francisco Press, San Francisco.

Brown, C.D., and Wise, M.A. (1991) Mineralogy and internal structure of the Black Mountain pegmatite, Oxford County, Maine. Geological Society of America Abstracts with Programs, 23, A329.

Hamlin, A.C. (1895) The history of Mount Mica of Maine, U.S.A., and its wonderful deposits of matchless tourmalines, 72 p. plus 63 plates. Hamlin, Bangor, Maine.

King, V.T. (1993) Geology of the state of Maine. In V.T. King, Ed., Geology and mineralogy of the state of Maine, p. 369–456. Maine Geological Survey, Bangor, Maine.

King, V.T., and Foord, E.E. (1993) Mineralogy of Maine. In V.T. King, Ed., Geology and mineralogy of the state of Maine, p. 73. Maine Geological Survey, Bangor, Maine.

Majling, J., Raninec, S., and Duroviic, S. (1979) Calculated powder diffraction patterns for anhydrous phosphates, p. 130–131. VEDA, Bratislava, Slovakia.

Mandarino, J.A. (1981) The Gladstone-Dale relationship. IV. The compatibility concept and its application. Canadian Mineralogist, 19, 441–450.

Meeker, G.P., and Quick, J.E. (1991) OPUS: Old probe-updated software. In D.G. Howitt, Ed., Microbeam analysis—1991, p. 353. San Francisco Press, San Francisco.

Moore, P.B., Araki, Takaharu, Steele, I.M., Swihart, G.H., and Kampf, A.R. (1983) Gainesite, sodium zirconium beryllophosphate: A new mineral and its crystal structure. American Mineralogist, 68, 1022–1028.

Morris, M.C., McMurdie, H.F., Evans, E.H., Paretzkin, B., Parker, H.S., Wong-Ng, W., and Gladhill, D.M. (1985) United States National Bureau of Standards standard X-ray diffraction powder patterns. Monograph, 25, Section 21, 112–113.

Sljukic, M., Matkovic, B., Prodic, B., and Anderson, D. (1969) The crystal structure of $KZr_2(PO_4)_3$. Zeitschrift für Kristallographie, 130, 148–161.

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