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PENIKISITE, THE MAGNESIUM ANALOGUE OF KULANITE, FROM YUKON TERRITORY

J. A. MANDARINO AND B. D. STURMAN

Department of Mineralogy and Geology, Royal Ontario Museum, 100 Queen's Park, Toronto, Ontario M5S 2C6

M. I. CORLETT

Department of Geological Sciences, Queen's University, Kingston, Ontario K7L 3N6

ABSTRACT

Penikisite is the magnesium analogue of kulanite and occurs as zones in kulanite–penikisite crystals which are from the northeastern corner of Yukon Territory. In appearance and properties penikisite is very similar to kulanite. The mineral is blue to green, has a hardness of 4, has two fair to good cleavages {010} and {100}, D(meas.) 3.79 g/cm^3, D(calc.) 3.82 g/cm^3 for $Ba(Mg_{1.01}Fe_{0.83}Ca_{0.16})Al_2(PO_4)_2(OH)_3$. Penikisite is biaxial (+), $n\alpha$ 1.684, $n\beta$ 1.688, $n\gamma$ 1.705, $2V(\gamma)=56°$(meas.) and 52°(calc.); X grass green, Y blue green, Z pale pink, absorption $X\sim Y>Z$. The mineral shows asymmetrical dispersion with strong dispersion of the optic axes. $r\gg v$. Orientation $c:Z=-6°$, $b\cong Y$ but ranges from 0° to 19°. Penikisite is triclinic (pseudomonoclinic), space group $P\bar{1}$ or $P1$, a 8.999, b 12.069, c 4.921Å, $\alpha\sim90°$, β 100°31′, $\gamma\sim90°$, $Z=2$. Strongest lines in the X-ray powder diffraction pattern are: 8.81(60)(100), 3.094(100)($\bar{2}21$,031), 3.028(60)($\bar{1}31$), 2.915(80)(211), 2.684(60)($\bar{3}11$), and 2.649Å(70)(320).

SOMMAIRE

La pénikisite est l'analogue magnésien de la kulanite. Elle se présente en zones dans des cristaux de kulanite–pénikisite qui proviennent du coin nord-est du territoire du Yukon. Par son aspect et ses caractères, la pénikisite ressemble beaucoup à la kulanite. Sa couleur passe du bleu au vert. Elle possède deux clivages assez bons et une dureté de 4. Ds (mes.) 3.79, Ds(calc.) 3.82 avec la formule $Ba(Mg_{1.01}Fe_{0.83}Ca_{0.16})Al_2(PO_4)_3(OH)_3$. Optiquement, elle est biaxe positive et pléochroïque: 1.684 (vert tendre), 1.688 (vert bleu), 1.705 (rose pâle); absorption $X\sim Y>Z$; $2V(\gamma)=56°$ (mes.), 52° (calc.). Elle montre une dispersion asymétrique, avec forte dispersion des axes optiques, $r\gg v$. On observe $c:Z=-6°$, $b:Y=0$ à 19°. La pénikisite est triclinique, pseudomonoclinique: de groupe spatial $P1$ ou $P\bar{1}$; a 8.999, b 12.069, c 4.921Å, $\alpha\sim90°$, β100°31′, $\gamma\sim90°$, $Z=2$. Les raies les plus intenses du diagramme de poudre sont données à la fin du sommaire en anglais (espacement, intensité, indices de Miller).

(Traduit par la Rédaction)

INTRODUCTION

Shortly after kulanite, $BaFe_2Al_2(PO_4)_3(OH)_3$, (Mandarino & Sturman 1976) had been approved by the Commission on New Minerals and Mineral Names, IMA, a second occurrence of the mineral was found, less than one km from the first. Detailed study of the new "kulanite" revealed that the crystals are strongly zoned. The Mg:Fe ratios vary greatly and parts of some crystals have Mg>Fe. These Mg-rich zones have been named penikisite in honor of Mr. Gunar Penikis who, with Mr. Alan Kulan, discovered the phosphate occurrence in the northeastern corner of the Yukon. The mineral and name were approved by the Commission on New Minerals and Mineral Names, IMA. The name is pronounced PĚNĪ•KĬSAIT. Type material is preserved in the collections of the Royal Ontario Museum (ROM No. M34172).

PHYSICAL PROPERTIES

Penikisite has the same general appearance as kulanite. The penikisite zones are generally near the edges of kulanite-penikisite crystals. These zones do not follow the crystal outlines. The penikisite zones are easily distinguished from those of kulanite, which are darker. All physical, optical, and X-ray measurements were obtained from material selected under a petrographic microscope.

Penikisite is blue to green and has a very pale green to white streak. The mineral is transparent to translucent, has a vitreous lustre, and is non-fluorescent under short-wave and long-wave ultraviolet light. The hardness is about 4 and there are two fair to good cleavages {010} and {100}. The density measured with a Berman balance is 3.79 (2) g/cm^3. The density calculated for $Ba(Mg_{1.01}Fe_{0.83}Ca_{0.16})Al_2(PO_4)_3(OH)_3$ is 3.82 g/cm^3.

Optical Data

Penikisite is biaxial (+) with $n\alpha$ 1.684(2), $n\beta$ 1.688(2), $n\gamma$ 1.705(2), $2V(\gamma)=56°$ (meas.) and 52.2° (calc.), all in sodium light. Penikisite is pleochroic with X grass-green, Y blue-green, Z pale pink; absorption, $X\sim Y>Z$. The mineral has very strong asymmetrical dispersion with dispersion of the optic axes $r\gg v$. The orientation of the indicatrix is $b\sim Y$ and $c:Z=-6°$, although $b:Y$ ranges from 0° to 19°.

Two types of zoning have been observed. One is a simple color zoning from dark blue to very pale blue. Microprobe analyses show that the pale zones have more Mg than the dark zones. The second type of zoning is more complicated and consists of zones which have different orientations of the principal vibration direction Y. In some zones Y is nearly parallel to b, but in others the angle $b:Y$ is as large as 19°. The latter have very strong asymmetrical dispersion and show anomalous extinction between crossed nicols. Precession camera films show that the crystallographic axis b is continuous in all zones in a crystal. This second type of zoning does not seem to be related to the Mg:Fe ratio.

Crystallography

Although penikisite is morphologically and dimensionally monoclinic, the asymmetrical dispersion indicates lower symmetry, as is the case with kulanite. Penikisite is triclinic, space group $P\bar{1}$ or $P1$, a 8.999, b 12.069, c 4.921Å, $\alpha\sim90°$, β 100°31′, $\gamma\sim90°$, V 525.49Å^3, $Z=2$, $a:b:c \simeq 0.7456:1:0.4077$. The unit-cell parameters were determined by least-squares refinement of the X-ray powder diffraction data. The powder data (Table 1) are almost identical to those of kulanite. Intensities of the lines in the X-ray powder pattern were estimated by eye from several films prepared with various exposure times. By comparing intensities of the stronger lines on films of shorter exposures, slight differences in intensities were easily observed. Intensities of the weaker lines were determined from films of shorter exposure. Because penikisite and kulanite grade into each other in single crystals, the morphological data for the two minerals are the same.

TABLE 1. X-RAY POWDER DIFFRACTION DATA FOR PENIKISITE (ROM M 34172)

I	d_{obs}	d_{calc}	hkl	I	d_{obs}
60	8.81	8.85	100	5	2.005
5	6.03	6.03	020	5	1.977
40	5.00	4.99	120	15	1.951
30	4.62	4.61	$\bar{1}01$	1	1.905
55	4.49	4.49	011	10	1.879
5	4.303	4.310	$\bar{1}11$	5	1.845
5	4.160	4.154	210	2	1.833
50	3.569	3.568	220	1	1.814
20	3.461	3.458	$\bar{2}11$	1	1.805
5	3.305	3.306	121	2	1.796
		3.097	$\bar{2}21$	5	1.786
100	3.094	3.093	031	2	1.770
60	3.028	3.032	$\bar{1}31$	1	1.761
20	2.978	2.976	230	1	1.753
80	2.915	2.914	211	2	1.728
30	2.863	2.865	310	2	1.706
20	2.854	2.856	140	7	1.679
40	2.812	2.819	131	5	1.667
55	2.692	2.689	221	5	1.657
		2.686	$\bar{2}31$	1	1.639
60	2.684	2.683	311	15	1.624
70	2.649	2.650	320	1	1.616
5	2.525	2.525	$\bar{1}41$	7	1.599
5	2.501	2.503	$\bar{3}21$	10	1.573
1	2.496	2.493	240	15	1.558
30	2.450	2.450	$\bar{1}02$	1	1.547
40	2.418	2.419	002	15	1.527
		2.401	$\bar{1}12$	2	1.520
1	2.398	2.398	141	40	1.496
10	2.377	2.378	330	20	1.490
15	2.263	2.266	$\bar{2}12$	25	1.464
		2.178	321	1	1.436
10	2.176	2.176	410	10	1.425
30	2.139	2.139	$\bar{1}51$	5	1.411
		2.093	122	7	1.396
10	2.094	2.092	132	2	1.373
		2.039	421		
10	2.036	2.036	312		
10	2.033	2.033	341		
30	2.011	2.011	060		

Guinier camera, Cu$K\alpha$ radiation, intensities estimated visually

Thermal and Chemical Data

Simultaneous DTA-TGA showed a weight loss of 3.88% and an endothermic peak at 710°C. The conditions of the analysis are the same as those given for kulanite by Mandarino & Sturman (1976) except that the analysis was performed in an air atmosphere.

Grains of kulanite–penikisite were analyzed using an Applied Research Laboratories – AMX electron microprobe, equipped with a Tracor-Northern NS-880 energy-dispersive spectrometer. Operating conditions were: accelerating voltage, 15 kV; sample current, about 1.5 nanoamperes; beam diameter, about 2 microns. Overlapping spectra were unravelled with a multiple least-squares fitting technique (program ML, written by F. Schamber, Tracor-Northern Ltd.). In order to use this analytical method, it is

TABLE 2. CHEMICAL ANALYSES OF KULANITE-PENIKISITE GRAINS

	Grain A	Grain B	Grain C		Grain D					
	1	2	3	4	5	6	7	8	9	10
MgO	5.0	4.6	5.9	6.0	6.5	6.1	5.5	6.7	5.4	6.4
CaO	0.3	0.1	0.5	0.6	1.4	1.3	1.1	0.0	0.0	0.2
MnO	1.0	0.4	0.1	0.0	0.0	0.4	0.2	0.1	0.5	0.3
FeO	13.9	15.1	12.9	12.8	9.5	10.1	11.8	12.8	14.7	12.0
BaO	23.4	23.9	24.7	24.5	24.9	24.6	24.2	24.8	24.3	24.7
Al_2O_3	17.0	16.9	16.9	17.2	18.0	17.5	17.5	16.5	16.1	16.8
P_2O_5	36.8	36.8	36.5	36.7	37.1	36.4	36.2	36.7	36.7	36.7
H_2O	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9
Total	101.3	101.7	101.4	101.7	101.3	100.3	100.4	101.5	101.6	101.0

H_2O by thermogravimetric analysis. Other constituents by electron microprobe.

necessary to have standard reference spectra which are free of overlapping peaks. The following standards were used as analytical as well as spectral standards: Mg(MgO), Al(Al_2O_3), P($Ca_2P_2O_7$), Ca($CaAl_2Si_2O_8$), Mn(Mn), Fe(Fe_2SiO_4), Ba($BaAl_2Si_2O_8$). Apparent concentrations were corrected for absorption, secondary fluorescence, and atomic-number effects using a general ZAF program, TAPEEMX 2 (Dep. Geol. Sci., Queen's University).

Twenty-eight analyses were made of zoned kulanite–penikisite crystals. Of these, ten were considered acceptable (Table 2) on the basis that the totals (including 3.9 wt. % H_2O determined by thermogravimetric analysis of the bulk sample) were between 98.2 and 101.8 wt. %. Table 3 shows the number of ions calculated on the basis of 15 oxygen ions for each analysis. Two of the analyses have Mg dominant and eight have Fe dominant. Thus, the analyses represent two penikisite compositions and eight kulanite compositions. Table 3 gives the Mg:Fe ratios as well as the numbers of ions of Mg, Ca, Mn, and Fe based on a total of 2.00. The formula calculated from the data of analysis 5 is: $Ba_{0.96}(Mg_{0.95}Fe_{0.78}Ca_{0.15})_{\Sigma=1.88}Al_{2.09}P_{3.09}O_{12.44}(OH)_{2.56}$ or, ideally,

$Ba(Mg_{1.01}Fe_{0.83}Ca_{0.16})_{\Sigma=2}Al_2(PO_4)_3(OH)_3$.

The specific refractive energy of penikisite calculated from analysis 5 is 0.179. The constant calculated from the refractive indices and the measured density is 0.183.

TABLE 3. NUMBER OF IONS BASED ON 15 OXYGEN IONS

	Grain A	Grain B	Grain C		Grain D					
	1	2	3	4	5	6	7	8	9	10
Mg	0.74	0.69	0.88	0.89	0.95	0.91	0.82	1.00	0.81	0.95
Ca	0.03	0.01	0.05	0.06	0.15	0.14	0.12	-	-	0.02
Mn	0.08	0.03	0.01	-	-	0.03	0.02	0.01	0.04	0.03
Fe	1.16	1.26	1.08	1.06	0.78	0.85	0.99	1.07	1.23	1.00
Ba	0.91	0.94	0.97	0.95	0.96	0.96	0.95	0.97	0.96	0.97
Al	2.00	1.99	1.99	2.01	2.09	2.06	2.07	1.94	1.90	1.98
P	3.11	3.11	3.09	3.09	3.09	3.08	3.08	3.10	3.12	3.10
H	2.59	2.60	2.60	2.58	2.56	2.60	2.61	2.59	2.61	2.60
Mg:Fe	0.64	0.54	0.82	0.84	1.22	1.08	0.83	0.93	0.65	0.95
Mg	0.74	0.69	0.87	0.88	1.01	0.94	0.84	0.96	0.78	0.95
Ca	0.03	0.01	0.05	0.06	0.16	0.14	0.12	-	-	0.02
Mn	0.08	0.03	0.01	-	-	0.04	0.02	0.01	0.04	0.03
Fe	1.15	1.27	1.07	1.06	0.83	0.88	1.02	1.03	1.18	1.00
Total	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00

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REFERENCE

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