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Vuoriyarvite $(K, Na)_2(Nb, Ti)_2Si_4O_{12}(O, OH)_2 \cdot 4H_2O$— A New Mineral from Carbonatites of the Vuoriyarvi Massif, Kola Peninsula[1]

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The mineral was found in veins of dolomite–calcite carbonatites crossing pyroxenites of the alkaline–ultrabasic Vuoriyarvi massif, Kola Peninsula. The vuoriyarvite segregations are confined to the solution cavities formed during the dolomitization of pyrochlore-bearing calcitic carbonatites. The mineral associates with calcite, dolomite, strontianite, evaldite, serpentine and apatite group minerals, pyrrhotite, pyrite, chalcopyrite, and sphalerite. The mineral was formed during the hydrothermal alteration of pyrochlore.

Vuoriyarvite forms tabular crystals with the faces of a rhombic prism {*h*01} and pinacoids {001}, {100} (see figure). The size of crystals along the long axis attains 3 mm.

The mineral is characterized by the following properties: white and dull; semitransparent; vitreous luster; brittle; uneaven fracture; white streak; cleavage is absent; the weakly pronounced jointing is perpendicular to the elongation hardness 4.5; microhardness 315–435 kg/mm^2 at the load 30 g; density (g/cm^3): measured in heavy liquids 2.95(2), estimated from the empirical formula 3.02(1), estimated using the rule of Gladstone-Dayle 2.87; luminescence is absent in the ultraviolet light and cathode rays; biaxial, positive, $n_g = 1.759(3)$, $n_m = 1.655(3)$, $n_p = 1.649(2)$, $2V = 20(5)$; weak dispersion, $r < v$; negative elongation $N_g = c$, $N_p = b$.

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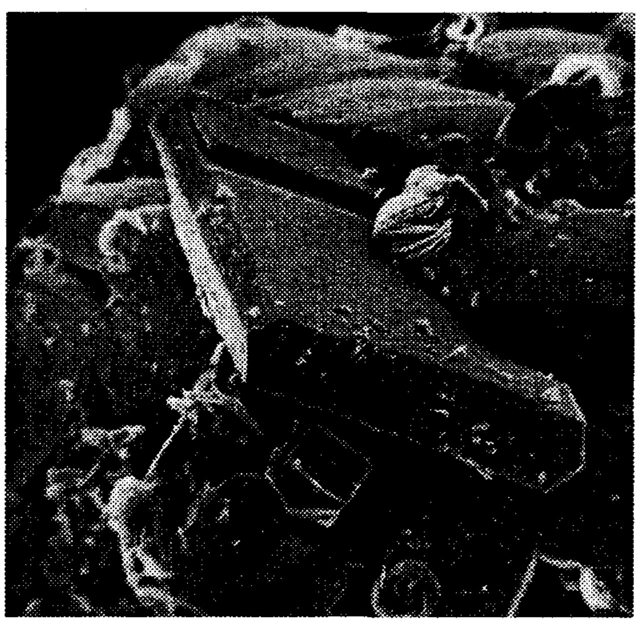
The mineral does not dissolve in diluted HCl and H_2SO_4. The IR-spectrum of the mineral contains the following absorption bands (in cm^{-1}; the intense ones are distinguished with boldface type): 3640, 3590. **3400**, 1750, **1645**, 1610, **1135**, **1090**, **938**, 740, **690**, 598, **468**, 440, 364, and 324.

An X-ray spectral microanalysis was made with the use of the following standards: lorenzenite (for Na and Ti), wadeite (K), diopside (Ca, Si), barite (Ba), hematite (Fe), and metallic Nb. The chemical composition, based on the result obtained, is presented in Table 1. Elements with an atomic number of less than 11 (Be, B, C, and Li) were not detected.

The empirical formula of the mineral estimated for Si = 4 is:

$$(K_{1.01}Na_{0.59}Ba_{0.14})_{\Sigma 1.74}(Nb_{1.84}Ti_{0.07})_{\Sigma 1.91}(Si_2O_6)_2O_{1.68} \cdot 4.19H_2O.$$



Tabular crystal of vuoriyarvite. SEM photo, magn. 180 reproduction 2/3.

Table 1. The chemical composition of vuoriyarvite, wt %

Oxide	1	2
Na_2O	2.80	2.70–3.00
K_2O	7.30	7.00–7.50
CaO	0.02	0.00–0.05
BaO	3.18	2.93–3.68
Fe_2O_3	0.03	0.03–0.05
TiO_2	0.81	0.68–1.08
Nb_2O_5	37.50	37.40–37.60
SiO_2	36.80	36.60–37.30
H_2O	11.56*	10.46–11.96
Total	100.00	

Note: (1) The composition of a single crystal (the average from measurements at 10 points); (2) the variations of composition based on the analysis of three different crystals from one specimen; the values estimated from the difference to 100% are marked with the asterisk.

The ideal formula of the mineral is:

$$(K, Na)_2(Nb, Ti)_2Si_4O_{12}(O, OH)_2 \cdot 4H_2O.$$

In other specimens taken from the Vuoriyarvi massif carbonatites, the mineral has a variable composition. The Nb:Ti ratio attains 1:0.9. In this case, the K:Na ratio varies from 3:1 to 2:1. The amount of the structural H_2O varies from 2 to 4 molecules. The titanous varieties of the mineral retain the structure of vuoriyarvite, but in this case, the elementary cell volume is somewhat reduced, which results in the corresponding changes of physical properties.

Based on the monocrystal study carbonatites, the mineral is referred to the monoclinic syngony with the *Cm* space group, a = 14.692(4), b = 14.164(4), c = 7.859(3) Å, β = 117.87(2)°, V = 1445.7(5) Å^3, and Z = 4. The X-ray diffraction pattern of the mineral powder contains 97 lines, (analytical conditions: the camera

Table 2. Interplanar distances of vuoriyarvite, Å

I	d_{meas}	d_{est}	*h k l*	*I*	d_{meas}	d_{est}	*h k l*
9	7.10	7.082	0 2 0	<1w	2.205	2.202	–1 3 3
3	6.51	6.495	–2 0 1	<1w	2.160	2.165	6 0 0
		6.494	2 0 0	1	2.092	2.093	1 1 3
6	4.98	4.960	0 2 1	2	2.070	2.069	–7 1 2, –6 2 3,
<1	4.53	4.566	–3 1 1				6 2 0
		4.437	1 3 0	<1w	2.052	2.055	4 4 1
2	3.915	3.918	–2 0 2, 2 0 1	<1	2.028	2.028	3 3 2
1	3.727	3.700	–1 1 2	<1	1.992	1.993	–6 4 2, –6 4 1
10	3.262	3.261	–4 2 1			1.992	–5 5 2
8w	3.151	3.155	0 4 1	3	1.953	1.953	0 6 2
	3.121	3.119	0 2 2	3	1.944	1.945	–7 1 3
<1w	3.034	3.013	3 1 1	3	1.913	1.915	5 5 0
6	2.956	2.955	1 1 2			1.913	–7 3 2
1w	2.890	2.900	–3 3 2	2	1.887	1.888	4 2 2, –4 2 4
		2.862	–5 1 1			1.886	1 7 1
<1w	2.673	2.748	–5 1 2	1w	1.856	1.866	–3 7 1
		2.664	–1 5 1	3	1.841	1.840	7 1 0
3	2.629	2.627	–2 4 2	<1	1.823	1.823	–1 1 4
		2.627	2 4 1	1w	1.782	1.778	–6 2 4
1	2.574	2.569	–3 1 3	3	1.774	1.776	–8 0 3, –8 0 1
4	2.549	2.549	–4 4 1			1.775	–5 3 4
1	2.523	2.524	–4 0 3, 4 0 1			1.773	–3 7 2
3	2.483	2.485	–5 3 1	1	1.748	1.748	–2 6 3, 2 6 2
<1	2.450	2.452	– 1 1 3	4	1.723	1.724	–4 6 3, 4 6 3
1w	2.389	2.393	4 4 0			1.723	–7 1 4
		2.378	–4 2 3			1.722	–8 2 3, –8 2 1
<1	2.370	2.370	3 5 0	2	1.715	1.716	5 1 2, 0 8 1
1	2.280	2.278	–1 5 2			1.714	4 4 2, –4 4 4
<1	2.242	2.244	–3 5 2				

Table 3. The basic parameters of vuoriyarvite, labuntsovite, and nenadkevichite

Parameter	Vuoriyarvite	Labuntsovite [6]	Nenadkevichite [7]
	$(K, Na)_2(Nb, Ti)_2 \cdot Si_4O_{12}(O, OH)_2 \cdot 4H_2O$	$(K, Ba, Na)(Ti, Nb) \cdot (Si, Al)_2(O, OH)_7 \cdot H_2O$	$(Na, Ca, K)(Nb, Ti) \cdot Si_2O_6(O, OH) \cdot 2H_2O$
Syngony	Monoclinic	Monoclinic	Rhombic
Space group	*Cm*	*I2/m*	*Pbam*
a, Å	14.692	14.180	7.328
b, Å	14.164	15.480	14.123
c, Å	7.859	13.700	7.115
β°	117.87	117.00	90
Strong lines of X-ray diffractogram, Å (*I*)	7.100(9)	3.150(10)	7.108(100)
	6.510(3)	3.090(8)	6.498(40)
	4.980(7)	2.560(9)	5.009(40)
	3.262(10)	1.677(8)	3.256(90)
	3.151(8⁻)	1.543(9)	3.178(50)
	2.956(6)	1.413(9)	2.554(40)
D_{meas}, g/cm³	2.95	2.96	2.84
n_p	1.649	1.689	1.639
n_m	1.655	1.702	
n_g	1.759	1.795	1.740
(+)2*V*	25	40	14

114.6 mm, FeK_α and CrK_α radiation). The reflections above 1.7 Å are presented in Table 2.

The study of the crystalline structure of the mineral (1443 nonzero reflections, $R = 0.055$) has shown its structural similarity to nenadkevichite and labuntsovite [1–5]. The distribution of Nb and Ti between two crystallographically independent octahedral positions with a mixed composition is established in the vuoriyarvite structure. K, Na, and H_2O have statistical distribution over intraskeleton positions. The ideal crystallochemical formula following from the results of monocrystal investigation is: $(K, Na)_2(Nb, Ti)(Nb, Ti)Si_4O_{12}(O, OH)_2 \cdot nH_2O$ at $n \sim 2$.

The estimated structure reveals a noncorrespondence of the number of water molecules to the chemical composition of the mineral. This may be explained by the difficulties connected with the localization of the molecules under the conditions of differential synthesis and weak site occupancy.

Therefore, vuoriyarvite (hydrous Nb–Ti silicate of K and Na–is a new representative of the nenadkevichite–labuntsovite group (Table 3).

The mineral is named vuoriyarvite after the place of its finding: Lake Vuoriyarvi, the alkaline–ultrabasic Vuoriyarvi massif, Kola Peninsula. The reference specimen of the mineral is in the depository of the Fersman Mineralogical Museum, Moscow.

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