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Kukharenkoite-(Ce), Ba₂Ce(CO₃)₃F, a new mineral from Kola peninsula, Russia, and Québec, Canada

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Abstract: Kukharenkoite-(Ce), ideally Ba₂Ce(CO₃)₃F, is a new rare-earth fluorocarbonate mineral, occurring as an accessory mineral in the late REE-carbonatites and REE-rich carbonate-zeolite rocks of the Khibina massif, Kola peninsula, Russia. It has also been found in other associations within the Khibina complex as well as in the Vuorijärvi massif, Kola peninsula and the related alkaline intrusions of the Mont Saint-Hilaire complex and the Saint-Amable sill, Québec, Canada. Kukharenkoite-(Ce) occurs in cavities as small (0.01-1.0 mm), prismatic, bladed crystals which are often in dendritic or stellate groups up to 2-3 mm across. Associated minerals are manganoan ankerite, ferroan rhodochrosite, manganoan siderite, natrolite, synchysite-(Ce), orthoclase, barite, pyrite, cordylite-(Ce), mckelveyite-(Y), ewaldite, galena and sphalerite. The mineral is yellow with a white streak; transparent with a vitreous lustre. Cleavage and parting were not observed. The microhardness VHN₂₅ is 280(25), the Mohs hardness is 4.5; density (meas.) is 4.7(1) g/cm³ and density (calc.) is 4.62 g/cm³. The infrared absorption spectrum includes the following bands: v_4 685-695-705-715-735; v_2 870-885; v_1 1090; v_3 1380-1430-1480 cm⁻¹. It is optically biaxial (-), with α 1.584(1), β 1.724(3), γ 1.728(3) (for Na light), $2V_{meas.}$: 16(1)°, $2V_{calc.}$: 18(1)°, $Z\Lambda c = 26.5^{\circ}$ in obtuse β , Y = b. On the Khibina specimens, an average of 12 electron-microprobe analyses gave CaO 0.39, SrO 1.55, BaO 47.39, La₂O₃ 6.61, Ce₂O₃ 15.30, Pr₂O₃ 1.19, Nd₂O₃ 4.26, Y₂O₃ 0.15, CO₂ 21.95 (calculated by stoichiometry), F 3.18, $-O = F_2$ 1.34, total 100.63. The ideal formula is Ba₂Ce(CO₃)₃F. The mineral is monoclinic, P_{21}/m , with a 13.396(7), b 5.067(1), c 6.701(1) Å, β 106.58(1)°, V 435.8(3) Å³, Z = 2. The strongest five X-ray powder diffraction lines [d in Å(I)(hkl)] are: 4.000(100)(201), 3.269(100)(310), 2.535(20)(020), 2.140(40)(221), 2.003(40)(402). The name kukharenkoite-(Ce) is given in honour of Professor A.A. Kukharenko (1914-1993; Department of Mineralogy, St-Petersburg University, Russia).

Key-words: kukharenkoite-(Ce), fluorocarbonate, new mineral, Khibina, Vuorijärvi, Mont Saint-Hilaire, Saint-Amable.

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Introduction

In 1986, a monoclinic Ba-REE-Th-bearing fluorocarbonate mineral, designated as UK-65. was identified from the Mont Saint-Hilaire alkaline complex, Québec, Canada (Chao et al., 1990). However, the small amount of material available for study precluded a complete investigation. In 1988, a mineral with similar crystallographic data to UK-65 was found in the Khibina and Vuorijärvi alkaline massifs, Kola peninsula, Russia. On the basis of its chemistry it was described as "zhonghuacerite-(Ce)", although a single crystal study showed the mineral to be monoclinic (Yakovenchuk et al., 1991: Zaitsev, 1992). In 1993, a mineral with similar crystallographic and chemical data as those for the Mont Saint-Hilaire, Khibina and Vuorijärvi minerals was identified in specimens collected in 1976 from the Saint-Amable sill, near the village of Varennes, Québec, Canada. A joint investigation of this mineral from all its localities during 1993-1995 showed that it is a new Ba-REE fluorocarbonate with the formula Ba2REE (CO₃)₃F where Ce is the dominant rare-earth element. This new mineral has been named kukharenkoite-(Ce) (in accordance with the Levinson system of nomenclature of REE minerals) in honour of Professor Alexander A. Kukharenko (1914-1993; Department of Mineralogy, St-Petersburg University, Russia), in recognition of his outstanding contributions to the geology, petrology and mineralogy of ultrabasic-alkalinecarbonatite complexes from the Kola peninsula. Russia. Both the mineral and mineral name have been approved by the Commission on New Minerals and Mineral Names of the I.M.A. (proposal 95-040). The cotype specimens are deposited in the Mineralogical Museum, Department of Mineralogy, St-Petersburg University, Russia under catalogue numbers 1/18303 (Khibina) and at the Canadian Museum of Nature, Ottawa, Ontario, Canada, under catalogue numbers CMNI 81531 (Khibina), CMNI 81532 (Mont Saint-Hilaire) and CMNI 81533 (Saint-Amable).

Mineral occurrences

Kukharenkoite-(Ce) is known from two alkaline massifs, Khibina and Vuorijärvi, which belong to the Kola alkaline province, Russia and from the Mont Saint-Hilaire alkaline complex and the Saint-Amable nepheline syenite sill which belong to the Monteregian Hills province, Canada.

The Khibina massif, covering an area of approximately 1327 km², is the largest intrusive complex of peralkaline nepheline syenites and foidolites in the world. It contains a wide variety of magmatic and metasomatic rocks that range from ultrabasics (pyroxenite) through alkaline rocks (foyaite, urtite, ijolite) to carbonatites (Kukharenko et al., 1971; Kogarko et al., 1995; Zaitsev, 1996). The Khibina massif is also wellknown for its unique mineralogy, where, together with the nearby Lovozero massif, approximately 500 mineral species are known to occur, 110 of which are new species (Britvin et al., 1995; Khomyakov, 1995). Kukharenkoite-(Ce) was discovered in the late REE-rich manganoan ankerite and ferroan rhodochrosite-manganoan ankerite carbonatites and REE-rich manganoan sideritemanganoan ankerite-natrolite rocks which are associated with foyaite (KH 1, KH 2, KH 3 samples), albite rock associated with fenite (KH 4 sample) and aegirine-feldspar rock associated with ijolite-urtite (KH 5 sample). The specimens were collected either from underground or from drill core sections. A compilation of associated species from the various locations within the Khibina massif include synchysite-(Ce), ewaldite, cordylite-(Ce), mckelveyite-(Y), orthoclase, barite, pyrite, sphalerite and galena (REE-rich carbonatites and carbonate-zeolite rocks), fluorite, zircon, burbankite and mckelveyite-(Y) (albite rock), natrolite, belovite, nenadkevichite, fluorite, ancylite-(Ce), calcite and ewaldite (aegirine-feldspar rock).

Vuorijärvi (20 km²) is not as well-known an alkaline massif as Khibina. It is characterized by a lesser degree of rock alkalinity than Khibina and contains mainly ultrabasic rocks (dunite, pyroxenite) and foidolites (ijolite, melteigite). Veins of phoscorites and carbonatites cross-cut ultrabasic and alkaline rocks and are widespread throughout the massif (Kukharenko *et al.*, 1965; Kogarko *et al.*, 1995). Kukharenkoite-(Ce) was found in the dolomite-calcite carbonatite (V I sample) and was collected from drill core. Associated species include: vaterite, alstonite, ancylite-(Ce), cordylite-(Ce), mckelveyite-(Y), fluorapatite and barite.

Mont Saint-Hilaire is a roughly circular alkaline intrusion approximately 3 km in diameter, which rises 350 m above the surrounding flat-



Fig. 1. Secondary electron images of kukharenkoite-(Ce) crystals. a - dendritic intergrowths (hexagonal crystal of ewaldite on left side of photograph), sample KH 1 (Khibina); b - detail of a; c - irregular intergrowths, sample KH 5 (Khibina); d - stellate intergrowths, sample V 1 (Vuoriyärvi).

lying Palaeozoic sedimentary rocks. The intrusion is Cretaceous in age and consists of 3 intrusions with different suites of igneous rocks ranging in composition from kaersutite-gabbro, to nepheline diorite and monzonite to peralkaline syenites, nepheline and sodalite syenites, phonolites and intrusive breccias (Currie *et al.*, 1986). A quarry on the east side of the mountain has exposed the most recent intrusion with nepheline syenite hosting pegmatitic veins, dykes and miarolitic cavities and numerous xenoliths of pre-existing igneous rock and hornfelsed sedimentary rock. It is from this quarry that over 300 mineral species have been identified, 29 of which are new species (Horváth & Gault, 1990). Kukharenkoite-(Ce) was found in thin seams in a hornfels xenolith associated with calcite, siderite, cordylite-(Ce), albite, quartz, pyrrhotite, pyrite and rutile (UK 65 sample).

The Saint-Amable alkaline sill is related to Mont Saint-Hilaire and other Cretaceous intrusions of the Monteregian Hills province. The sill, which is exposed by a large quarry, averages 15 m in thickness and forms at least part of a slightly elevated plateau approximately 100 km² in area. It consists mainly of fine-grained nepheline syenite with abundant natrolite. Tiny cavities in the syenite host a suite of some 100 minerals. Kukharenkoite-(Ce) occurs rarely as a late-stage mineral in the cavities, associated with microcline, natrolite, eudialyte, mangan-neptunite, aegirine, mosandrite, pyrite, zakharovite, yofortierite, låvenite, astrophyllite and calcite (VUK 12 sample).

Physical properties

Kukharenkoite-(Ce) occurs as a late-stage mineral in tiny cavities. In Khibina, Vuorijärvi and Mont Saint-Hilaire it forms small (0.01-1 mm) prismatic crystals which are often in dendritic, stellate or irregular intergrowths up to 2-3 mm across (Fig. 1; KH 1, KH 4, KH 5, V 1 and UK 65 samples); rarely the mineral occurs as platy crystals (0.1-2 mm) or anhedral grains (0.05-0.2 mm in size), closely associated with manganoan siderite and natrolite (KH 2 and KH 3 samples). In Saint-Amable, kukharenkoite-(Ce) occurs as tapering, bladed crystals from 0.3 to 1 mm in length forming reticulated aggregates to 3 mm across or as fine needles forming fibrous aggregates (VUK 12 sample).

The mineral is yellow or reddish-brown (due to inclusions of Fe-bearing opaque phases) from Khibina and Vuorijärvi, and colourless to very pale white to silvery grey or pinkish grey from Mont Saint-Hilaire and Saint-Amable. The streak is white. It is transparent to translucent with a vitreous to greasy lustre, but the reddish-brown variety is opaque and earthy. Cleavage or parting were not observed. It is brittle with an uneven fracture. No fluorescence in long- or short-wave ultraviolet radiation was observed. The Mohs' hardness is about 4.5 and for KH 2 sample (platy crystals) micro-indentation: VHN load 25 g, mean 280(25) kg/mm², range 250-320 kg/mm² (22 measurements were made on a polished block using Mikromet II). The measured density, determined by the microburette method for KH 2 sample, is 4.7(1) g/cm³, close to the values of 4.62-4.73 g/cm³ calculated from empirical formulas and refined cell dimensions for KH 1, KH 5, UK 65 and VUK 12 samples. The mineral is soluble in HCl with effervescence.

The optical properties of kukharenkoite-(Ce) were determined in Na light (589 nm), using a spindle stage and crystals previously oriented by X-ray goniometry (Table 1).

Table 1. Optical properties for kukharenkoite-(Ce).

Sample	KH 1	KH 4	UK-65	VUK 12
	b	iaxia	(-)
α	1.584(1)	1.586(3)	1.594(1)	1.593(1)
β	1.724(3)	not measured	1.710(3)	≈ 1.730
γ	1.728(3)	1.728(3)	1.715(3)	≈ 1.730
2V _{meas.}	16(1) ⁰	10-20 ⁰	16(1) ⁰	15(1) ⁰
2V _{calc.}	18 ⁰		22 ⁰	
$Z\Lambda c$ in obtuse β	26.5°		26.5°	26.5°
	Y=b		Y=b	Y=b
dispersion		r > v,		
		medium		

Infra-red spectroscopy

The infrared-absorption spectrum of kukharenkoite-(Ce) was obtained utilizing a UR-20 Carl Zeiss spectrophotometer (Geological Institute, Apatity). About 2-3 mg of the mineral from KH 1, KH 2 and KH 5 samples, were ground and pressed into KBr pellets, and the infrared-absorption spectra were recorded over the region 400-3800 cm⁻¹. IR spectra obtained from the KH 1, KH 3 and KH 5 samples are identical in positions of absorption bands as well as in their intensities. The spectrum of kukharenkoite-(Ce) (Fig. 2) is characterised by strong absorption in the regions 675-745, 850-900, 1060-1100 and 1200-1600 cm⁻¹



Fig. 2. Infra-red spectrum of kukharenkoite-(Ce).

which indicate that the mineral contains a carbonate group, but no OH or H_2O groups (White, 1974).

The free anion $(CO_3)^2$ has been known to have four normal IR-active vibration modes; in the infrared spectrum of the kukharenkoite-(Ce) the relevant wavenumbers have the following values: v_4 685-695-705-715-735; v_2 870-885; v_1 1090; v_3 1380-1430-1480 cm⁻¹. The splitting of the v_3 and v_4 vibration modes suggest the presence of at least two non-equivalent carbonate groups in the cell.

Sample	KH1	KH2	КНЗ	KH5	UK 65	VUK 12
Number of analyses	12	3	17	2	1	1
Na ₂ O	bd	bd	0.08	bd	0.14	bd
CaO	0.39	0.06	0.05	0.43	0.38	0.06
MnO	-	bd	0.26	-	-	-
FeO	-	0.42	bd	-	0.10	bd
SrO	1.55	0.62	0.42	2.04	2.29	0.05
BaO	47.39	49.82	48.93	48.80	47.63	50.07
La ₂ O ₃	6.61	6.32	6.16	10.44	5.77	10.27
Ce ₂ O ₃	15.30	13.57	15.12	10.34	9.91	14.32
Pr ₂ O ₃	1.19	1.25	1.49	bd	bd	0.37
Nd ₂ O ₃	4.26	3.41	4.08	1.74	1.31	1.47
Sm ₂ O ₃	bd	0.11	bd	bď	bd	bd
Gd ₂ O ₃	-	-	-	-	0.20	bd
Y_2O_3	0.15	bd	bđ	0.72	bd	bd
ThO ₂	-	0.76	0.10	-	7.61	bd
F	3.18	2.98	3.20	3.05	3.31	3.14
CO ₂	21.95	21.57	21.73	21.17	20.72	21.45
-O=F2	1.34	1.25	1.35	1.28	1.39	1.32
Total	100.63	99.64	100.27	97.45	97.98	99.88

Table 2. 0	Chemical	composition	of kukharen	koite-(Ce).
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Structural formulas calculated on the basis of 3 atoms of C

KH 1 $(Ba_{1.86}Sr_{0.09}Ca_{0.04})_{\Sigma 1.99}(Ce_{0.56}La_{0.24}Nd_{0.15}Pr_{0.04}Y_{0.01})_{\Sigma 1.00}(CO_3)_3F_{1.01}$

 $KH\ 2 \qquad (Ba_{1.99}Sr_{0.04})_{\Sigma^2.03}(Ce_{0.51}La_{0.24}Nd_{0.12}Pr_{0.05}Fe_{0.04}Th_{0.02}Ca_{0.01})_{\Sigma^0.99}(CO_3)_3F_{0.96}$

 $\mathsf{KH}\ 3 \qquad (\mathsf{Ba}_{1.94}\mathsf{Sr}_{0.03}\mathsf{Mn}_{0.02}\mathsf{Ca}_{0.01})_{\Sigma^{2}.00}(\mathsf{Ce}_{0.56}\mathsf{La}_{0.23}\mathsf{Nd}_{0.15}\mathsf{Pr}_{0.06})_{\Sigma^{1}.00}(\mathsf{CO}_{3})_{3}\mathsf{F}_{1.02}$

 $\mathsf{KH}\ 5 \qquad (\mathsf{Ba}_{1.99}\mathsf{Sr}_{0.12})_{\Sigma 2.11}(\mathsf{La}_{0.40}\mathsf{Ce}_{0.39}\mathsf{Nd}_{0.06}\mathsf{Ca}_{0.05}\mathsf{Y}_{0.04})_{\Sigma 0.94}(\mathsf{CO}_3)_3\mathsf{F}_{1.00}$

UK 65 (Ba1.98 Sr0.14) 52.12 (Ce0.38 La0.23 Th0.18 Nd0.05 Ca0.04 Na0.03 Gd0.01 Fe0.01) 50.93 (CO3) 3 F1.11

VUK 12 Ba_{2.01}(Ce_{0.54}La_{0.39}Nd_{0.05}Pr_{0.01}Ca_{0.01}) $_{\Sigma 1.00}$ (CO₃) $_{3}$ F_{1.02}

bd = below detection limit, - = not sought.

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	KH 1			KH 5			UK 65		VUK 12			
1	d _{meas.}	d _{calc.}	1	d _{meas.}	d _{calc.}		d _{meas.}	d _{calc.}	1	d _{meas.}	d _{calc.}	hkl
100	4.000	4.0052	90	4.000	3.9933	100	4.015	4.0129	100	3.995	3.9967	1 11
		4.0047			3.9932			4.0127			3.9966	201
100	3.269	3.2693	100	3.264	3.2604	100	3.273	3.2751	100	3.261	3.2627	310
		3.2694			3.2597			3.2753			3.2624	202
		3.2682			3.2594			3.2735			3.2611	401
20	2.535	2.5330	70	2.527	2.5260	20	2.539	2.5377	50	2.526	2.5282	020
		2.5331			2.5257			2.5381			2.5280	112
40	2.140	2.1408	50	2.138	2.1348	40	2.143	2.1448	60	2.135	2.1366	221
		2.1407			2.1344			2.1452			2.1364	003
		2.1399			2.1339			2.1435			2.1353	512
40	0 000	2.1398	~~	4 007	2.1342	60	0.007	2.1436		4 000	2.1353	600
40	2.003	2.0024	60	1.997	1.9967	50	2.007	2.0064	80	1.998	1.9983	402
		2.0021			1.9900			2.0059			1.9980	511
		2.0024			1.9900			2.0060			1.9984	222
		2.0022			1.9903			2.0056			1.9900	313 101
5	1 700	1 70021	20	1 783	1.9900	10	1 702	1 7022	10	1 796	1 7864	421 603
J	1.750	1 7902	30	1.705	1 7855	10	1.752	1 7033	10	1.700	1 7865	711
10	1 635	1.6350	30	1.631	1.6305	30	1 637	1 6380	20	1 631	1 6319	131
	11000	1.6346	00		1.6302	Ç,	11001	1.6376	20		1.6313	620
		1.6351			1.6304			1.6384			1.6318	313
		1.6341			1.6297			1.6368			1.6306	802
		1.6347			1.6299			1.6377			1.6312	404
5	1.571	1.5709	20	1.571	1.5662	10	1.574	1.5740	10	1.568	1.5677	114
		1.5708			1.5664			1.5739			1.5677	<u>4</u> 22
10	1.373	1.3732	25	1.369	1.3694	20	1.376	1.3755	20	1.369	1.3703	822
		1.3732			1.3693			1.3755			1.3702	714
		1.3732			1.3695			1.3756			1.3703	<u>9</u> 10
		1.3735			1.3697			1.3759			1.3707	<u>5</u> 32
		1.3735			1.3695			1.3760			1.3707	424
		1.3735		4 0 0 0	1.3697			1.3761			1.3707	712
			15	1.330	1.3307							10.01
					1.3311							333
					1.3311							205
					1.0009							200
					1 3307							013
			10	1 263	1 2627							731
			10	1.200	1 2628							821
					1 2625							515
					1.2629							224
					1.2630							040
			5	1.208	1.2076							11.01
					1.2080					_		341

Table 3. X-ray powder diffraction data for kukharenkoite-(Ce).

Chemical composition

Both energy- and wavelength-dispersion analyses of kukharenkoite-(Ce) were made using a Cameca MS-46 electron microprobe at 20 kV and 20 nA (Geological Institute, Apatity), a JEOL 733 Superprobe with Tracor-Northern automation at 15 kV, 20 nA and 30 μ m beam (Canadian Museum of Nature, Ottawa) and a Cameca SX 50 electron microprobe at 15 kV, 10 nA and 20 μ m beam (The Natural History Museum, London). The following standards were used: lorenzenite (Na), diopside (Ca), celestine (Sr), barite (Ba), synthetic phases (La,Ce)S (La, Ce), LiPr(WO4)₂ (Pr), LiNd(MoO4)₂ (Nd), LiSm(MoO₄)₂ (Sm), YAl₅O₁₃ (Y) and ThO₂ (Th) (Geological Institute, Apatity); vlasovite (Na), calcite and gehlenite (Ca), celestine (Sr), sanbornite and barite (Ba), synthetic phases LaPO₄ (La), CePO₄ (Ce), PrPO₄ (Pr), NdPO₄ (Nd), GdPO₄(Gd), BaFe₁₂O₁₉ (Fe), LiF and synthetic LaCO₃F (F) and ThO₂ (Th) (Canadian Museum of Nature, Ottawa); jadeite (Na), apatite (Ca), celestine (Sr), synthetic calcium aluminium silicate glasses obtained from the University of Edinburgh (REE), pure Mn (Mn), Fe (Fe), Th (Th) and BaF₂ (Ba, F) (The Natural History Museum, London). F determinations in the Khibina KH 1, KH 2 and KH 5 samples were made by wet micro-chemical analysis and confirmed by microprobe. It was unfortunately not possible to obtain enough material for direct determination of CO_2 content.

The analytical results are given in Table 2. They show that kukharenkoite-(Ce) contains Ba, REE and F as major elements and Sr, Ca, Th and Fe as minor elements. An exception to this is the mineral from Mont Saint-Hilaire which is characterized by a high Th content (7.61 wt.% ThO₂). The atomic ratios of Ba, REE and F are near 2:1:1, which requires 3 (CO₃)²⁻ groups per formula unit. Calculated empirical formulas (Table 2) suggest that the ideal formula for the mineral is Ba₂REE(CO₃)₃F.

The mineral is strongly light-REE-enriched with Ce as a dominant element and Y content near the detection limit. For the mineral from the aegirine-feldspar rock (KH 5 sample) it is established that both La and Ce are present in similar amounts, atomic proportions being 0.40 for La and 0.39 for Ce. However, having taken into account the imprecision of the high overlap correction for Ba on Ce we conclude that the mineral from this sample cannot be designated as 'kukharenkoite-(La)'.

Using the Gladstone-Dale constants (Mandarino, 1976) and the analysis for KH 1, 1-(Kp/Kc) = 0.001, which indicates superior compatibility between the chemical and physical data.

X-ray crystallography

Precession X-ray studies of crystals from KH 1, KH 5 and UK 65 samples show that kukharenkoite-(Ce) belongs to the monoclinic system with space group $P2_1/m$ or $P2_1$. Structural analysis of synthetic Ba₂Ce(CO₃)₃F (Mercier & Leblanc, 1993b) confirmed the space group $P2_1/m$.

The cell parameters for both KH 1 and UK 65 samples were obtained from precession photographs and then refined by the least-squares method using powder diffraction lines (Gandolfi 114.6 mm camera, filtered CuK α radiation). Indexing was based on precession photographs, using only strong reflections. Cell parameters for the KH 5 sample were refined by the leastsquares method using DRON powder diffraction lines (DRON 2.0 diffractometer, filtered CuK α radiation) and those for VUK 12 sample were refined from powder data. X-ray powder diffraction data and unit cell parameters for kukTable 4. Crystallographic data for kukharenkoite-(Ce).

Sample	KH 1	KH 5	UK 65	VUK 12
Crystal syste	m m	onod	c l i n	i c
Space group)	P2	l₁/m	
a, Å	13.396(7)	13.360(9)	13.418(9)	13.367(9)
b, Å	5.067(1)	5.052(1)	5.077(1)	5.056(1)
c, Å	6.701(1)	6.681(2)	6.714(2)	6.687(2)
β, ^ο	106.58(1)	106.58(2)	106.56(2)	106.57(2)
V, Å ³	435.8(3)	432.2(4)	438.3(4)	433.2(5)
Z	2	2	2	2
D _{calc.} , g/cm ³	4.62	4.67	4.73	4.71

harenkoite-(Ce) are given in Table 3 and Table 4 respectively.

The crystallographic data for kukharenkoite-(Ce) are similar to those for the synthetic phase Ba₂Ce(CO₃)₃F, prepared by hydrothermal growth at T = 750°C and P = 200 MPa for 30 hours (Mercier & Leblanc, 1993a and b). The data for synthetic Ba₂Ce(CO₃)₃F are included in Table 5 for comparison. The structure of synthetic Ba₂Ce(CO₃)₃F has been solved by Mercier & Leblanc (1993b) (R = 0.019, Rw = 0.021) and it consists of CeO₉F, BaO₁₁ and BaO₇F₃ coordination polyhedra. The cerium polyhedra form infinite isolated chains parallel to the **b**-axis. The barium polyhedra form double chains along [010] and these double chains form infinite layers parallel to the (100) plane.

Discussion

The Ba-REE fluorocarbonates include the following four minerals: the new species and subject of this report, kukharenkoite-(Ce), Ba₂Ce(CO₃)₃F, huanghoite-(Ce), BaCe(CO₃)₂F (Semenov & Zhang, 1961; Kapustin, 1973; Yang & Pertlik, 1993), cordylite-(Ce), $BaCe_2(CO_3)_3F_2$ (Flink, 1901; Chen & Chao, 1975) and *cebaite-(Ce)*, Ba₃Ce₂(CO₃)₅F₂ (Zhang & Tao, 1983; Dunn et al., 1985; Yang, 1995). Three other reported Ba-REE fluorocarbonate phases are not accepted by IMA: "zhonghuacerite-(Ce)" (Zhang & Tao, 1981, 1986), although published, was never submitted to IMA and important discrepancies were noted by Fleischer et al. (1982); "cebaite-(Nd)" was found to equal cebaite-(Ce) (Jambor et al., 1988); "baiyuneboite-(Ce)" (Fu et al., 1987; Fu & Su, 1988) was rescinded before its publication,

	Kukharenkoite-(Ce)	"Zhonghuacerite-(Ce)"*	Synthetic**	
	Khibina	Bayan-Obo		
Formula Crystallography Space group Barameters	Ba₂(Ce,La)(CO₃)₃F monoclinic P2₁/m	Ba₂(Ce,La)(CO₃)₃F trigonal	Ba ₂ Ce(CO ₃) ₃ F monoclinic <i>P</i> 2 ₁ /m	
a Å	13 396	5.07	13 365	
h Å	5.067	0.07	5.097	
c. Å	6.701	9.82	6.638	
6.°	106.58		106.45	
V, Å ³	435.8	218.6	433.5	
z	2	1	2	
Strongest lines in th powder pattern, dme	e 4.000 (100), as(I) 3.269 (100), 2.535 (20), 2.140 (40), 2.003 (40)	3.92 (8), 3.419 (4), 3.216 (10), 2.512 (6), 2.123 (3), 2.103 (10), 1.979 (10), 1.638 (3), 1.572 (3)		
Physical properties		- (-)		
Colour Lustre D _{meas.} , g/cm ³	yellow vitreous 4.7	pale yellowish vitreous or greasy 4.20-4.40	4 702	
Hardness (Mot	4.02 (s) 4.5	4.00	4.702	
VHN Optical data	280	289-309		
	Biaxial (-) α 1.584 β 1.724 γ 1.728 2V _{meas} .16° 2V _{calc} .18°	Unaxial (-) ε 1.568 ω 1.745		

Table 5. Comparison of data for kukharenkoite-(Ce), "zhonghuacerite-(Ce)" and synthetic Ba₂Ce(CO₃)₃F.

* Zhang & Tao (1981). ** Mercier & Leblanc (1993a).

after it was found to equal cordylite-(Ce) whose original formula was incorrect (Jambor & Grew, 1990). A corrected formula for cordylite-(Ce), which contains essential Na, is not reported here pending a redefinition of the mineral (J. Zemann, pers. comm., 1996). Although there are a number of publications describing Ba-REE fluorocarbonate minerals, some mineral data (physical properties, chemical composition, X-ray diffraction data) are, however, often incomplete and sometimes inconsistent.

Kukharenkoite-(Ce) has a very strong rhombohedral subcell (a' = 5.076(1), c' =9.821(9) Å for UK-65) which is very close to the subcell of cebaite-(Ce) (a' = 5.071, c' = 9.740 Å) and huanghoite-(Ce) (a' = 5.026, c' = 9.747 Å; Peng & Shen, 1980). As only the strong sublattice reflections are recordable by the powder diffraction method, the powder pattern of kukharenkoite-(Ce), cebaite-(Ce) and huanghoite-(Ce) are therefore similar. This suggests a strong structural relationship among the three species which was discussed by Mercier & Leblanc (1993b). "Zhonghuacerite-(Ce)" was described and published (Zhang & Tao, 1981, 1986; Fleischer *et al.*, 1982) without approval of CNMMN of the IMA. The mineral was originally described as trigonal and uniaxial (-) (Table 5) and later revised as trigonal with a monoclinic superstructure and optically biaxial (-) with small $2V = 5^{\circ}$, α 1.565, β 1.732 and γ 1.745 (Zhang & Tao, 1986). "Zhonghuacerite-(Ce)" is almost certainly identical with kukharenkoite-(Ce). Unfortunately, we did not have any possibility of studying "zhonghuacerite-(Ce)" from Bayan Obo, because all the available material was used for previous investigations (P. Zhang, pers. comm. to A. Zaitsev, 1992).

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