

Florencite-(Sm)—(Sm,Nd)Al₃(PO₄)₂(OH)₆: A New Mineral Species of the Alunite–Jarosite Group from the Subpolar Urals¹

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Abstract—Florencite-(Sm), a new mineral species of the florencite subgroup, was found in association with xenotime-(Y) in quartz veins of the Maldynyrd Range of the Subpolar Urals as thin zones within rhombohedral crystals of florencite-(Ce) with faceting by {0111} and {1012}. The thickness of particular florencite-(Sm) zones is 0.01–0.1 mm, and the total thickness of a series of such zones is 1–3 mm. Florencite-(Sm) is colorless and pale pink or pale yellow with white streaks; its Mohs hardness is 5.5–6.0. Its measured and calculated densities are 3.70 and 3.743 g/cm³, respectively. The mineral is transparent, nonpleochroic, and uniaxial (positive), and $\omega = 1.704(2)$ and $\varepsilon = 1.713(2)$. The electron beam's fluorescence spectrum was 592 nm (intense green luminescence of Sm³⁺) and 558 nm (yellow luminescence of Nd³⁺). The chemical composition was as follows (microprobe, average of 2 WDS, wt %): 0.62 La₂O₃, 3.29 Ce₂O₃, 1.05 Pr₂O₃, 10.31 Nd₂O₃, 12.62 Sm₂O₃, 0.41 Eu₂O₃, 2.30 Gd₂O₃, 0.13 Dy₂O₃, 0.71 SrO, 0.35 CaO, 29.89 Al₂O₃, 26.14 P₂O₅, 0.85 SO₃, 0.09 SiO₂, 88.76 in total; 10.74 H₂O (meas.). The empirical formula based on 14 oxygen atoms is (Sm_{0.38}Nd_{0.32}Gd_{0.07}Ce_{0.10}Pr_{0.03}La_{0.02}Eu_{0.01}Sr_{0.04}Ca_{0.03})_{1.0}Al_{3.04}(P_{1.91}S_{0.05}Si_{0.01})_{1.97}O₁₄H_{5.92}. The idealized formula is (Sm,Nd)Al₃(PO₄)₂(OH)₆. Mineral is trigonal, space group *R3m*, $a = 6.972(4)$, $c = 16.182(7)$ Å, $V = 681.2$ Å³, $Z = 3$. The XRD pattern is as follows: $dln(I)(hkl)$: 2.925 (10) (113), 1.881 (6) (303), 2.161 (5) (107), 5.65 (4) (101), and 3.479 (4) (110). The IR spectrum: 466, 510, 621, 1036, 1105, 1223, 2957, and 3374 cm⁻¹.

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INTRODUCTION

Florencite-(Ce) was found in 1938 in placers at the Koiva River in the Central Urals (Labuntsov, 1949); florencite-(La) and florencite-(Nd) were described from the Glinka emerald and chrysoberyl occurrence (Popov and Kanonerov, 2000). In the Subpolar Urals, florencite-(Ce) was revealed in the Litoshkino occurrence of hydrothermal quartzite (Silaev et al., 2001). Florencite-(Ce) is known also from carbonatite of the Eastern Sayan (Somina and Bulakh, 1996). Florencites of complex composition are abundant in the Subpolar Urals (Fig. 1), where they are found in altered rocks, quartz veins, and orebodies of the Au–REE ore fields (Mel'nikova et al., 2005; Repina and Yuzeeva, 2005; Repina, 2010). Florencites from carbonatite of the Eastern Sayan have been studied in detail (Somina and Bulakh, 1966).

The large (up to 3 cm) crystals of pinkish florencite-(Ce) with an inner zone of florencite-(Nd) were

found in 2004 in fragments of hydrothermal quartz veins at the Svodovy site in the Maldynyrd Range in the Subpolar Urals (Repina and Yuzeeva, 2005). The veins are localized in the quartz conglomerate of the Lower Ordovician Obeiz Formation close to the contact with the underlying high-Al metasomatic rocks formed after the micaceous gravelstone of the Upper Cambrian–Lower Ordovician Al'kesvozh Formation. The veins up to 3 m thick are composed of milky and slightly smoky giant-grained quartz. In the selvages, quartz is intergrown with light blue tourmaline-asbestos (dravite); in the intermediate part of the veins, large ingrowths of florencite and xenotime-(Y) of the early generation are incorporated into quartz; and, in slit-shaped cavities in the central part of the veins and at their pinching, small rock crystals are intergrown with florencite-(Ce) and xenotime-(Y) of the late generation no larger than 0.5 cm in size.

Growth zones enriched in Sm were revealed in large florencite crystals (Repina, 2010). The detailed examination of such zones resulted in the identification of florencite-(Sm), an Sm-dominant member of the florencite subgroup.

Physical properties. Florencite-(Sm) occurs as thin zones in the pointed rhombohedral crystals of florencite-(Ce) (Fig. 2) mainly in the central part of the

¹ A new mineral species florencite-(Sm) and its name were recommended by the Commission on New Minerals and Mineral Names of the Russian Mineralogical Society on September 9, 2009 and approved by the Commission on New Minerals, Nomenclature, and Classification of the International Mineralogical Association on November 30, 2009 (IMA no. 2009-074).

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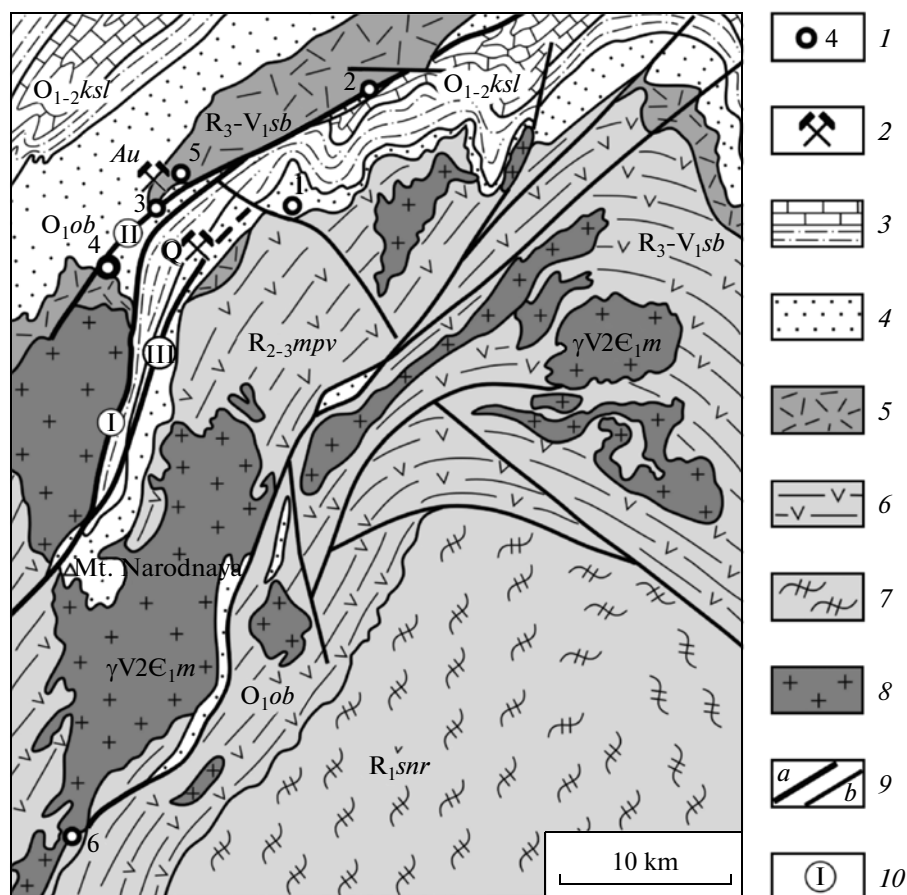


Fig. 1. Florencite occurrences in the Subpolar Urals. The geological base is modified after the Geological Map of the Urals on a Scale of 1 : 200 000 (2000).

(1) Florencite occurrences (numerals in the figure): 1, Mt. Chernaya; 2, Mt. Varsonof'eva; 3, Grubependity Cirque; 4, Svodovy site; 5, Al'kesvosh site; 6, Mt. Piramida; (2) the Zhelanny deposits of vein quartz (Q) and the Chudny Au-Pd-REE deposit (Au); (3) Lower-Middle Ordovician Kozhim and Saledy formations: limestone and silty shale; (4) Lower Ordovician Obeiz Formation: quartzitic sandstone, gravelstone, and conglomerate; (5) Upper Riphean-Lower Vendian Sablegorsky Formation: felsic and mafic volcanic rocks, tuffaceous slate; (6) Middle-Upper Riphean Moroina, Khobeina, and Puiva formations: marble, quartzite, phyllite, and schist; (7) Lower Riphean Shokur'ya and Nyarta formations: schist, gneiss, and amphibolite; (8) Late Vendian-Early Cambrian granite, granodiorite, and diorite of the Maldy and Kozhim complexes; (9a) faults, (9b) geological boundaries; (10) major faults (numerals in the figure): I, Maldy; II, Ozerny; III, Zhelanny.

rhombohedra growth $\{10\bar{1}1\}$ sectors and are not exhibited or poorly developed in the facing crystals, which are frequently characterized by predominant compromise growth surfaces with quartz and xenotime-(Y) (Fig. 3). The thickness of particular zones of florencite-(Sm) ranges from 0.01 to 0.1 mm, and the total thickness of a series of such zones reaches 1–3 mm. In the chips along the cleavage, these zones look yellowish or whitish against the pinkish matrix and are clearly seen in the characteristic X-ray radiation of $\text{Sm}L_\alpha$ (Fig. 4). Florencite-(Sm) is colorless; in aggregates, it is pale pink to pale yellow with white streak and greasy luster. The Mohs hardness is 5.5–6.0. The mineral is transparent to semitransparent, brittle; frac-

ture is uneven; cleavage is good parallel to $\{0001\}$; parting is parallel to $\{11\bar{2}0\}$. The density of the micrograins measured by equilibration in the Clerici aqueous solution with $n = 1.622$ is $3.60(1) \text{ g/cm}^3$; the density calculated on the basis of empirical formulas is $3.666\text{--}3.743 \text{ g/cm}^3$. In the flame of a blowpipe, florencite is fused hardly; in a closed tube, the mineral releases much water. Florencite poorly dissolves in HCl and HNO_3 .

The fluorescence spectrum of the powder of florencite-(Sm) recorded with a KLAVI-R CL analyzer contains two distinct bands (Fig. 5): at 592 nm (strong green luminescence of Sm^{3+}) and at 558 nm (yellow luminescence of Nd^{3+}).

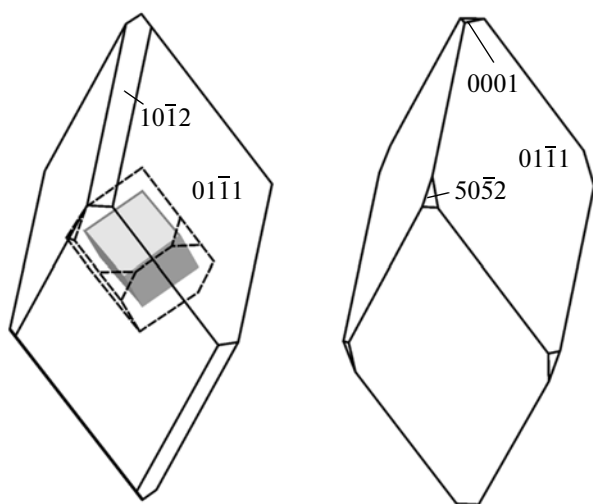


Fig. 2. Idealized shape of the florencite-(Ce) crystals with the inner zones of florencite-(Sm).

The infrared spectrum of the mineral (Fig. 6a) in a KBr disk was obtained with a NIKOLET NEXUS IR-Fourier spectrometer equipped with a CONTINUUM microscope. According to the data of Pluysnina (1977) and in the opinion of N.V. Chukanov, the strong band at 621 cm^{-1} and the band at 921 cm^{-1} correspond in phosphates to the bending vibrations of PO_4^{3-} and O—P—OH, respectively; the strong bands at 1036, 1105, and 1223 cm^{-1} are assigned to the stretching vibrations of P—O; and the bands at 2957 and 3374 cm^{-1} correspond to the stretching vibrations of the isolated O—H groups. The bands at 466 and 510 cm^{-1} (medium intensity) are suggested to be assigned to REE—O vibrations. The weak band in the region of $1600\text{--}1700\text{ cm}^{-1}$ indicates a small amount of H_2O molecules. In the IR

spectrum of florencite-(Sm), there are no bands corresponding to carbonate groups in the region of $1400\text{--}1500\text{ cm}^{-1}$ characteristic of Brazilian florencite-(La) (Fig. 6b).

In the thermogram recorded with a Q-1500 D derivatograph in the range of $13\text{ to }984^\circ\text{C}$ for a sample 1583 mg in weight, the endothermic effect caused by the loss of 10.74 wt % H_2O is displayed at 760°C (Fig. 7).

The optical parameters were measured in immersion liquids of the IZh-1 standard set produced by the Reactive Works in Lvov, Ukraine. In immersion liquids, florencite-(Sm) is colorless, transparent, nonpleochroic, uniaxial, and positive; $\varepsilon = 1.704(2)$, $\omega = 1.713(2)$, the birefringence is $0.009(2)$.

Morphology. As aforementioned, the crystals of florencite are pointed rhombohedral, but the areas of proper faces are rare. The forms of the mineral were measured with a universal stage as a goniometer, whereas inclusions of florencite grains in large lumps of quartz, with an applied goniometer. The crystals were constructed with the Shape 7.1 program at an X-ray ratio of $a : c = 1 : 2.32$. This made it possible to refine the previous data (Repina and Yuzeva, 2005; Repina, 2010) and establish that the areas of the rhombohedral faces $\{01\bar{1}1\}$ are developed on the crystal, the areas of narrow faces $\{10\bar{1}2\}$ are rare, and the minute faces $\{50\bar{5}2\}$ and $\{0001\}$ (Fig. 2) are still rarer; twins were not found. The zones of florencite-(Sm) occur largely in the middle part of the growth sectors ($10\bar{1}2$), but they are also found as continuous zones in the most abundant rhombohedra $\{10\bar{1}2\}$ and $\{01\bar{1}1\}$ (Figs. 3a, 4).

Similar to synthetic florencite-(Sm) (Schwab et al., 1990) and the other florencite-subgroup members, the symmetry of natural florencite-(Sm) is trigonal with

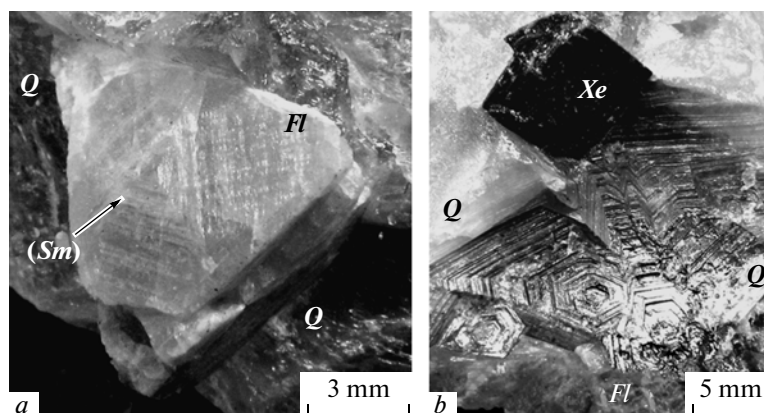


Fig. 3. (a) Light zones of florencite-(Sm) (Sm) in chipped crystal of florencite (Fl); (b) compromised growth surface between florencite and xenotime (Xe) and quartz (Q).

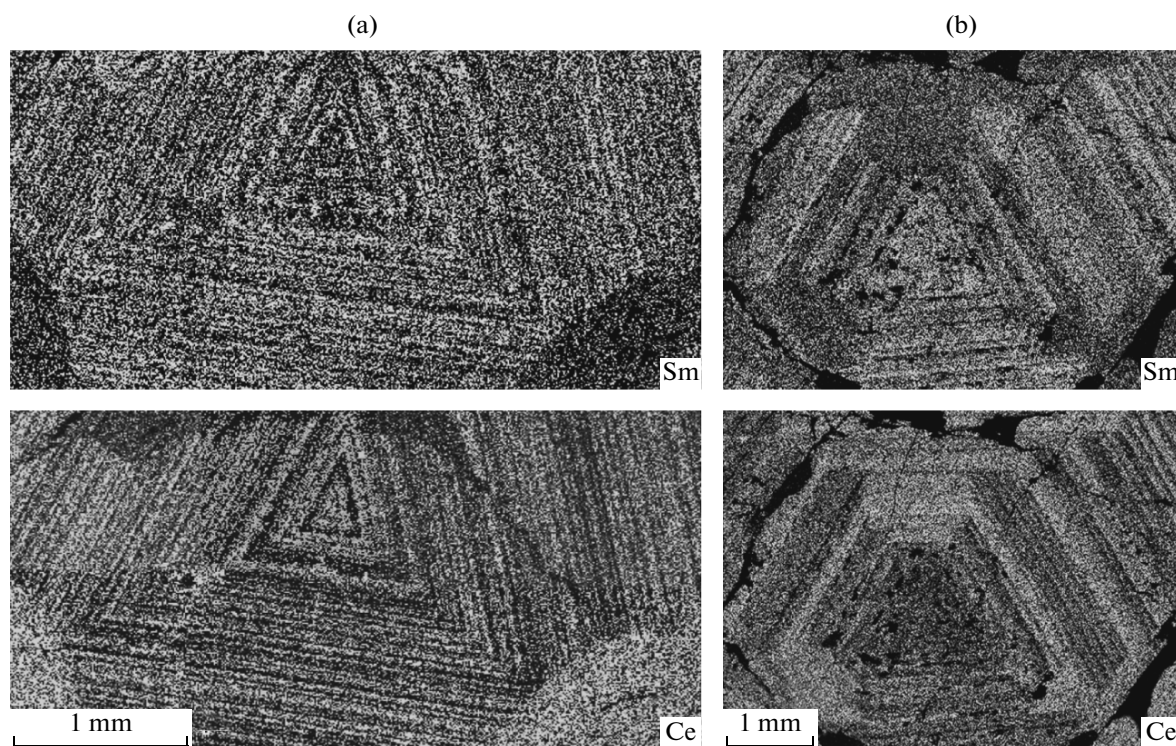


Fig. 4. Central parts of two florencite crystals with zones of florencite-(Sm) in characteristic $CeL_{\alpha 1}$ and $SmL_{\alpha 1}$ irradiation.

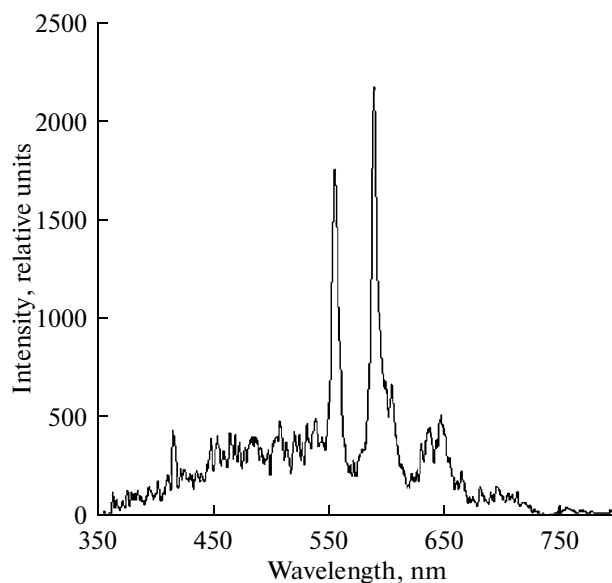


Fig. 5. Cathodoluminescence spectrum of florencite-(Sm).

space group $R\bar{3}m$; an X-ray single crystal study was not performed.

X-ray crystallography. The X-ray powder diffraction pattern of florencite-(Sm) was recorded with a Shimadzu XRD-6000 diffractometer with $CuK_{\alpha 1}$ radi-

ation with a monochromator; the rate of the recording was 0.5 degree/min, and the internal standard was Ge. The unit-cell dimensions calculated with the least squares method from 17 unique reflections beginning from $d = 3.479 \text{ \AA}$ (Table 1) are $a = 6.972(4)$ and $c =$

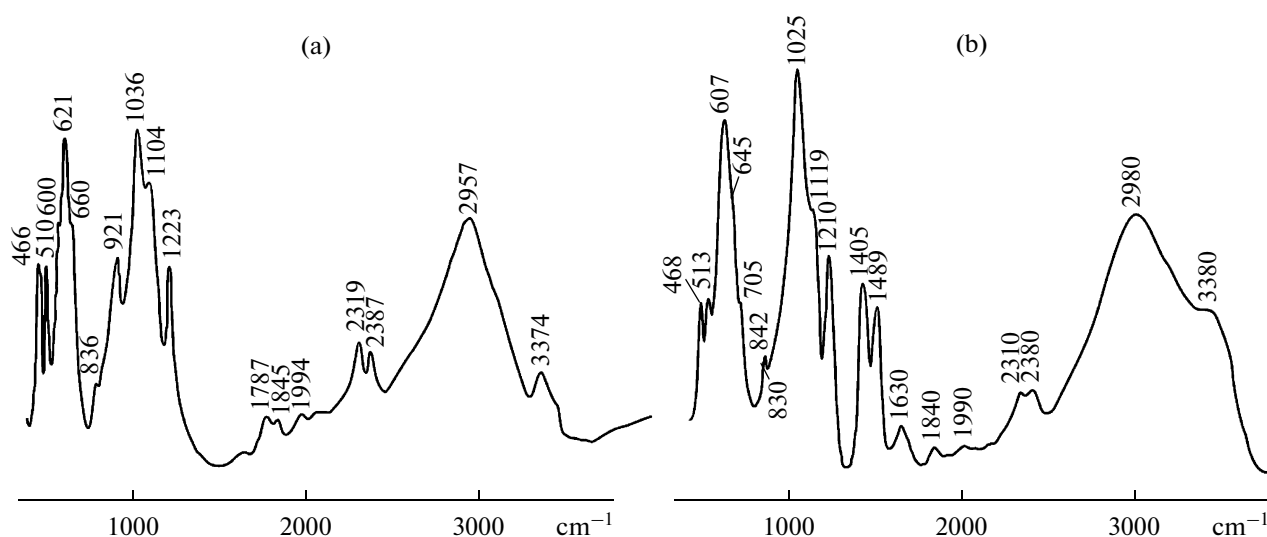


Fig. 6. IR spectra of (a) florencite-(Sm) and (b) florencite-(La).

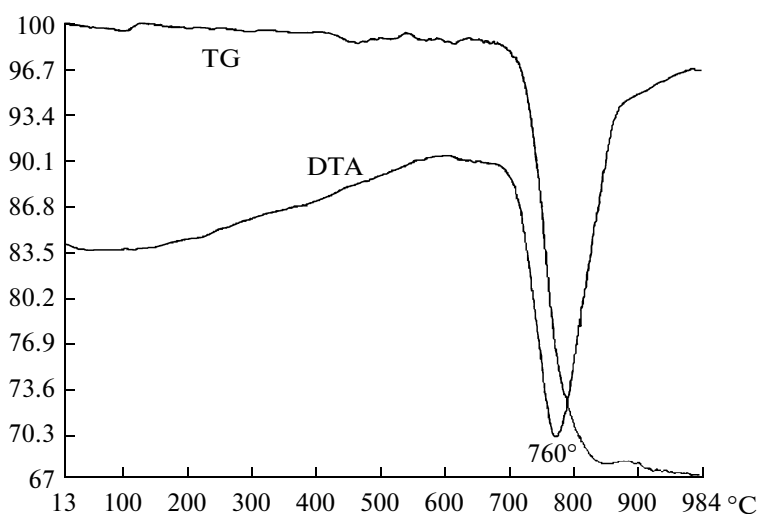


Fig. 7. Thermogram of florencite-(Sm).

16.182(7) Å. The 5.65 and 5.36 Å reflections were omitted because of the uncertainty of the d in the small-angle region. These data indicate that the d -spacings of natural florencite-(Sm) with a significant contribution of Nd are close to those of synthetic $\text{SmAl}_3(\text{PO}_4)_2(\text{OH})_6$ or intermediate between the latter and $\text{NdAl}_3(\text{PO}_4)_2(\text{OH})_6$. In the region of 2.19–2.20 Å, the X-ray powder diffraction pattern of florencite-(Sm) shows two reflections instead of one characteristic of the reference florencites. At the same time, the reference X-ray powder diffraction patterns of some members of the alunite–jarosite group crystallized in the same space group, for example, beaverite (PDF

no. 47-1817) and synthetic florencite-(La) (Schwab et al., 1990), demonstrate reflections 205 and 122. The indexing of both reflections gives satisfactory parity of the measured and calculated d -spacings. The occurrence of microinclusions of florencite-(Ce) with d -spacing 2.202 Å and indices 122 in the studied mineral has been disproved, because no other unique reflections of this mineral species are identified.

Chemical composition. The chemical composition of florencite-(Sm) was examined with a JXA-733 Geol Superprobe electron microprobe equipped with INCA EDS operating at an accelerating voltage of 20 kV, a current of 1 nA, and a beam diameter of 2–5 μm; the stan-

Table 1. X-ray powder diffraction patterns and unit-cell dimensions of florencite-(Sm) compared with synthetic SmAl₃(PO₄)₂(OH)₆, NdAl₃(PO₄)₂(OH)₆, and natural CeAl₃(PO₄)₂(OH)₆

Florencite-(Sm)				SmAl ₃ (PO ₄) ₂ (OH) ₆			NdAl ₃ (PO ₄) ₂ (OH) ₆			CoAl ₃ (PO ₄) ₂ (OH) ₆		
<i>I</i>	<i>d</i> _{meas} , Å	<i>hkl</i>	<i>d</i> _{calc} , Å	<i>I</i>	<i>d</i> , Å	<i>hkl</i>	<i>I</i>	<i>d</i> , Å	<i>hkl</i>	<i>I</i>	<i>d</i> , Å	<i>hkl</i>
43	5.65	101	5.657	80	5.636	101	60	5.650	101	80	5.65	101
7	5.36	003	5.394	5	5.329	003				5	5.42	003
							<5	4.828	012	5	4.85	012
37	3.479	110	3.486	65	3.475	110	45	3.483	110	60	3.48	110
11	3.363	104	3.351				5	3.351	104	15	3.36	104
100	2.925	113	2.924	100	2.911	113	100	2.924	113	100	2.93	113
9	2.822	202	2.827	85	2.816	202	15	2.828	202	15	2.83	015
16	2.700	006	2.686	10	2.665	006	10	2.686	006	15	2.71	006
12	2.418	024	2.416	15	2.402	024	10	2.415	024	20	2.42	024
8	2.255	211	2.260	19	2.251	211	10	2.260	211	10	2.26	211
17	2.206*	205	2.203							25	2.202	122
22	2.191	122	2.196	40	2.187	122	35	2.197	122			
46	2.161	107	2.151	30	2.135	107	25	2.152	107	40	2.170	107
15	2.132	116	2.128	15	2.113	116	10	2.128	116	10	2.139	116
							<5	2.012	030			
12	1.984	214	1.986	10	1.976	214	10	1.985	214	10	1.990	214
										5	1.927	018
58	1.881	303	1.885	40	1.877	303	35	1.885	303	40	1.886	303
										5	1.868	125
20	1.738	220	1.743	30	1.737	220	25	1.743	220	30	1.742	220
4	1.680	131	1.666							10	1.685	208
										5	1.661	223
6	1.623	217	1.621				5	1.621	217	10	1.627	217
7	1.599	119	1.593	10	1.581	119	<5	1.593	119	10	1.604	119
				5	1.479	315				5	1.570	1.0.10
				10	1.478	042	<5	1.484	042	15	1.486	042
				5	1.455	226	<5	1.462	226	15	1.466	226
<i>a</i> 6.972(4) <i>c</i> 16.182(7) Å <i>V</i> = 681.20 Å ³ <i>Z</i> = 3 <i>a</i> : <i>c</i> = 1 : 2.3210 This study				<i>a</i> 6.947(1) <i>c</i> 16.982(3) Å <i>V</i> = 667.97 Å ³ <i>Z</i> = 3 <i>a</i> : <i>c</i> = 1 : 2.3006 Schwab et al., 1990			<i>a</i> 6.972(1) <i>c</i> 16.116(3) Å <i>V</i> = 678.43 Å ³ <i>Z</i> = 3 <i>a</i> : <i>c</i> = 1 : 2.3115 Schwab et al., 1990			<i>a</i> 6.971(8) <i>c</i> 6.262(5) Å <i>V</i> = 684.36 Å ³ <i>Z</i> = 3 <i>a</i> : <i>c</i> = 1 : 2.3328 PDF No. 43-0673		

Note: A Shimadzu XRD-6000 diffractometer was used with monochromatized CuK α radiation (0.5 degree/min, analyst E.V. Belogub). The reflections Ge 3.269 and 2.000 Å are omitted. The indices of the reflections calculated on the basis of the real unit-cell dimensions are asterisked.

Table 2. Chemical composition (wt %) of florencite-(Sm) from the Subpolar Urals

Component	EDS						WDS			
	1	2	3	4	5	average	6	7	8	average
La ₂ O ₃	—	—	—	—	—	—	0.60	0.54	0.73	0.62
Ce ₂ O ₃	1.62	0.78	2.81	3.04	1.33	1.92	3.31	2.94	3.61	3.29
Pr ₂ O ₃	0.80	—	—	—	—	0.16	1.07	0.98	1.11	1.05
Nd ₂ O ₃	11.11	7.94	10.85	9.93	7.57	9.35	10.20	10.42	10.30	10.31
Sm ₂ O ₃	13.29	12.72	11.93	13.37	13.47	12.96	12.03	13.32	12.52	12.62
Eu ₂ O ₃	—	—	—	—	—	—	0.43	0.40	0.39	0.41
Gd ₂ O ₃	2.86	3.01	2.28	2.16	2.42	2.55	2.47	2.29	2.13	2.30
Dy ₂ O ₃	—	—	—	—	—	—	0.40	—	—	0.13
SrO	1.92	2.74	1.64	0.58	2.65	1.91	0.72	0.72	0.68	0.71
CaO	0.52	1.49	0.53	0.31	1.02	0.77	0.41	0.32	0.31	0.35
Al ₂ O ₃	28.33	29.19	29.30	32.01	32.19	30.20	30.44	29.30	29.92	29.89
P ₂ O ₅	28.33	27.69	27.42	27.06	25.42	27.18	25.80	26.53	26.08	26.14
SO ₃	1.70	3.33	1.12	1.13	3.37	2.13	0.83	0.81	0.92	0.85
SiO ₂	—	—	—	—	—	—	0.09	0.06	0.12	0.09
H ₂ O	—	—	—	—	—	10.74*	—	—	—	10.74*
Total	90.48	88.99	87.87	89.59	89.44	99.87	88.80	88.63	88.82	99.50

Note: The H₂O was determined by DTA (Fig. 7); the dash denotes that the content of the element is below the detection limit; the As, Ba, Pb, F, and Cl contents are also below the detection limit. EDS: a JXA-733 electron microprobe equipped with INCA EDS, analyst E.I. Churin. WDS: a Cameca SX-100 electron microprobe, analyst V.V. Khiller.

dards were SmP₅O₁₄, GdP₅O₁₄, monazite-(Ce), diopside, celestine, and pyrope. The variations in the chemical compositions and the average concentrations are shown in Table 2 (analyses 1–5). The empirical formula of the aver-

age EDS composition based on 14 oxygen anions is (Sm_{0.37}Nd_{0.28}Gd_{0.07}Ce_{0.06}Pr_{0.01}Sr_{0.09}Ca_{0.07})_{1.95}Al_{2.97}(P_{1.92}S_{0.13})_{2.05}O₁₄H_{5.98}; the idealized formula is (Sm,Nd)Al₃(PO₄)₂(OH)₆. The calculated density is

Table 3. Comparative characteristics of florencite-(Sm), synthetic SmAl₃(PO₄)₂(OH)₆, and florencite-(Nd)

Parameter	Florencite-(Sm)	SmAl ₃ (PO ₄) ₂ (OH) ₆	Florencite-(Nd)
Formula	(Sm,Nd)Al ₃ (PO ₄) ₂ (OH) ₆	SmAl ₃ (PO ₄) ₂ (OH) ₆	(Nd,Ce)Al ₃ (PO ₄) ₂ (OH) ₆
Crystal habit	Zones (0.01–1 mm) in pointed rhombohedral florencite-(Ce) crystals	Rhombohedral crystals (3–10 μm)	No data
Color	Colorless to pale pink and pale yellow	No data	Yellow, pink
Luster	Vitreous, greasy	"	Resin—greasy
Mohs hardness	5.5—6	"	5—6
Density, g/cm ³	3.60 (meas.) 3.743 (calc.)	3.903 (calc.)	3.52 (meas.) 3.74 (calc.)
Optical parameters	ε 1.713(2), ω 1.704(2)	No data	ε 1.73, ω 1.72
Chemical composition, wt %	La ₂ O ₃ 0.62; Ce ₂ O ₃ 3.29; Pr ₂ O ₃ 1.05; Nd ₂ O ₃ 10.31; Sm ₂ O ₃ 12.62; Eu ₂ O ₃ 0.41; Gd ₂ O ₃ 2.30; Dy ₂ O ₃ 0.13; SrO 0.71; CaO 0.35; Al ₂ O ₃ 29.81; P ₂ O ₅ 26.14, 27.18; SO ₃ 0.85; SiO ₂ 0.09; H ₂ O (meas.) 10.74; Total 99.50	Sm ₂ O ₃ 33.3(3); Al ₂ O ₃ 28.3(3); P ₂ O ₅ 26.9(2); H ₂ O (meas.) 11.5(1) Total 100.0	Ce ₂ O ₃ 7.95; Nd ₂ O ₃ 24.45; Al ₂ O ₃ 29.63; P ₂ O ₅ 27.50; H ₂ O (meas.) 10.47 Total 100.0
Symmetry	Trigonal	Trigonal	Trigonal
Space group	$R\bar{3}m$	$R\bar{3}m$	$R\bar{3}m$
Strong reflections in the X-ray powder diffraction pattern, Å	2.925, 1.881, 2.161, 5.65, 3.479	2.911, 2.816, 5.636, 3.475, 2.187, 1.877	2.93, 2.17, 5.56
Unit-cell dimensions	a 6.972(4) Å	a 6.947(1) Å	a 6.98 Å
	c 16.182(7) Å	c 15.982(3) Å	c 16.28 Å
	V 681.20 Å ³	V 667.97 Å ³	V 686.90 Å ³
	$Z = 3$	$Z = 3$	$Z = 3$
	$a : c = 1 : 2.3210$	$a : c = 1 : 2.3006$	$a : c = 1 : 2.3324$
Mode of occurrence	Hydrothermal quartz veins hosted in conglomerate, the Subpolar Urals, Russia	Synthetic (Schwab et al., 1990)	Chert, California, USA (www.webmineral.com/data/Florencite-(Nd).shtml)

3.666 g/cm³. The compatibility of the physical properties (K_p) and the chemical composition (K_c) of the florencite-(Sm) calculated with the Gladstone—Dale

criterion is $C = 1 - (K_p/K_c) = -0.0004\sum k_i p_i/100$, where n is the mean refraction, D is the density, p_i denotes the content of the oxide in the average compo-

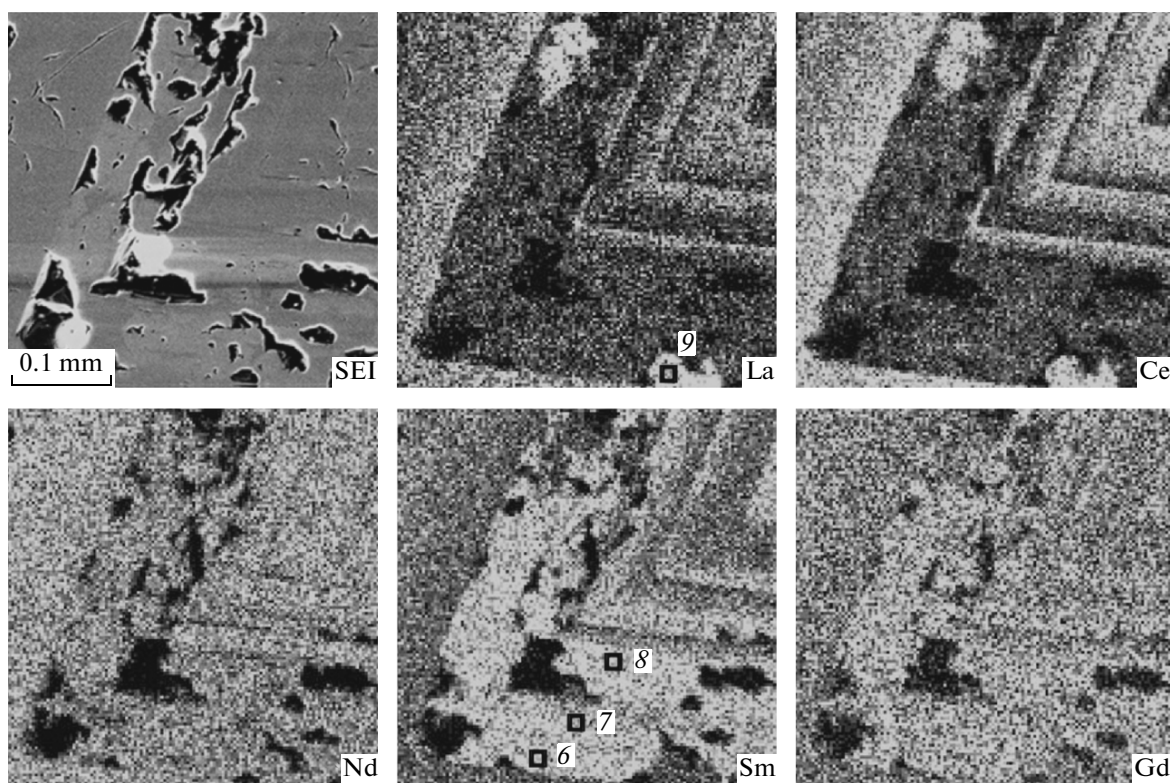


Fig. 8. BSE image of a zonal florencite-(Sm) crystal and the distribution of La, Ce, Nd, Sm, and Gd (images in characteristic irradiation). Points 6, 7, and 8 are WDS measurements corresponding to the analyses in Table 2; point 9 is an inclusion of florencite-(Ce).

sition of florencite, and k_i is the energetic coefficient of the oxide.

According to the recommendation by the Commission on New Minerals, Nomenclature, and Mineral Classification, the IMA and REE in the mineral were measured with a Cameca SX-100 electron microprobe equipped with five wavelength spectrometers (WDS) operating at 15 kV, 20 nA, and a beam diameter of 2 μ m. MPO4 synthetic phosphate glasses, where M is REE from La to Dy, were the standards; in addition, CaSiO₃, GaAs, celestine (Sr, S), and jadeite (Al, Si) were used as standards. The additional results are close to the data obtained with EDS, while differing only in a higher admixture of La, Ce, Pr, and Eu and a lower content of Ca, Sr, and S (Table 2, analyses 6–8). The formula of florencite-(Sm) calculated for the average WDS composition taking into account the H₂O content of 10.74 wt % looks like (Sm_{0.38}Nd_{0.32}Gd_{0.07}Ce_{0.10}Pr_{0.03}La_{0.02}Eu_{0.01}Sr_{0.04}Ca_{0.03})_{1.00}Al_{3.04}(P_{1.91}S_{0.05}Si_{0.01})_{1.97}O₁₄H_{5.92} and in general is close to that calculated from the EDS data. According to the refined data, the calculated density of florencite-(Sm) is 3.743 g/cm³; the compatibility of the chemical composition and physical properties is –0.028.

The rhythmic alternation of florencite-(Sm), -(Nd), and -(Ce) resembling oscillatory zoning is

observed in the central part of growth sectors $\langle 1011 \rangle$ (Fig. 4). The X-ray mapping of the REE and concentration patterns of Sm, Nd, and Ce (Figs. 8, 9) indicate the prevalence of Sm over Na and Ce and chemical substitution in florencite.

According to the X-ray mapping, some zones of florencite-(Sm) contain microinclusions (0.05 mm) of florencite-(Ce) significantly enriched in LREE and As, whereas the Sm concentration is below the detection limit in these inclusions (Fig. 8, point 9). The empirical formula is (Ce_{0.51}La_{0.30}Nd_{0.11}Pr_{0.03}Eu_{0.01}Gd_{0.01}Sr_{0.01}Ca_{0.01})_{0.99}Al₃(P_{1.79}As_{0.08}S_{0.06}Si_{0.06})_{1.99}O₁₄H_{6.23}.

The comparison of florencite-(Sm) with synthetic SmAl₃(PO₄)₂(OH)₆ and natural florencite-(Nd) indicates that some parameters of florencite-(Sm) are intermediate between those of these two compounds (Table 3). The crystallization of florencite-(Sm) in association with HREE minerals is possible from solutions enriched in HREE and MREE. For example, at the Svodovy site, xenotime-(Y) associated with florencite contains up to 11–23 wt % Gd₂O₃ and 7–8 wt % Dy₂O₃ (Repina, 2010). Florencite-(Sm) zones were probably formed as a result of REE fractionation and periodically oscillating oversaturation at the front of the growing crystals. The subgroup of florencite com-

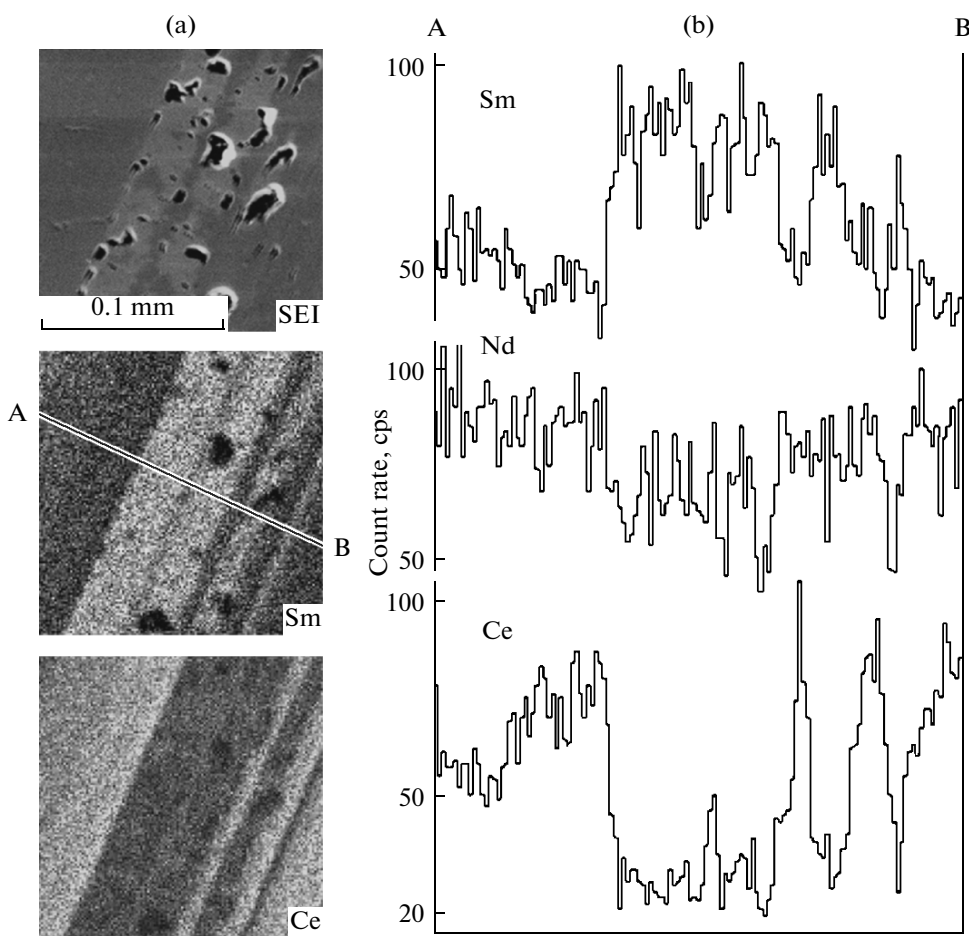


Fig. 9. Alternation of florencite-(Sm), -(Nd), and -(Ce) zones: (a) a BSE image and the distribution of the Sm and Ce (images in characteristic irradiation) and (b) the Sm, Nd, and Ce concentrations along profile A–B.

prising florencite-(La), -(Ce), and -(Nd) is supplemented by florencite-(Sm), a new Sm-dominant member. The type material of the new mineral is deposited at the Natural Museum of the Ilmeny State Reserve of the Institute of Mineralogy of the Urals Branch of the Russian Academy of Sciences in Miass (reg. no 17228).

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