MINERALS OF THE PEGMATITES AND HYDROTHERMAL ASSEMBLAGES OF THE KOASHVA DEPOSIT (Khibiny, Kola Peninsula, Russia)

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The Khibiny alkaline massif in the Kola Peninsula is known by every mineralogist. It is a world champion for the number of new minerals discovered in one geological environment; at present, these are 115, while the total mineral species found in Khibiny is 550. The massif has been studied for more than 120 years; hundreds of mineralogical papers have been published, and every year brings new discoveries. Three reviews (Bonshtedt *et al.*, 1937; Kostyleva-Labuntsova *et al.*, 1978b; Yakovenchuk *et al.*, 2005) are "*time shear*" summing up the results of the study of minerals from the Khibiny massif over time.

Peralkaline pegmatites and hydrothermal assemblages are the most diverse and curious in mineralogical aspect in Khibiny. Most new minerals and other findings are related to them; owing to these assemblages the Khibiny massif has become one of the greatest mineralogical localities worldwide.

The giant magmatic apatite deposits have been mined for more than 80 years and their reserves are not exhausted. The extensive works in the open and underground mines are very important for the development of the mineralogy of the massif: mining opens new interesting features including occurrences of peralkaline hyperagpaitic mineralization, which contain minerals unstable to weathering and not found at the surface.

1. The Koashva open pit and dumps. Photo: I.V. Pekov. 2007.

2. Derrick no. 520 at the Koashva deposit. December, 1966.
Photo taken from geological open file report (Kamenev *et al.*, 1967).

3. Koashva Mount and Vuonnemiok river valley before mining in 1960s.
Photo taken from geological open file report (Kamenev *et al.*, 1967).

4. Koashva Mount and Koashva open pit at present (view of NE to SW).
Photo: R.V. Semenov. 2007.

5. Mining of apatite ore in the Koashva open pit. Photo: I.V. Pekov. 2007.

6. Loading of apatite ore in railroad train in the ore warehouse of the Koashva open pit. 2008. Photo by S.I. Pekov.

and B (lisitsynite) minerals are few and are found in insignificant amounts except for chkalovite and barytolamprophyllite. Sulfide mineralization is diverse and sporadically rich, including alkaline (djerfisherite, chlorbartonite, rasvumite, and murunskite) and hydrous (orickite and wilhelmramsayite) sulfides. Organic matter as segregations of black and dark brown solid bitumen frequently enriched in rare elements (*REE*, Th, Sr, Ba, Nb) are typical of most pegmatites. The largest nodules (up to 15 cm) and the richest accumulations of bitumen were found in the Koashva-2008 pegmatite. They were radioactive because of a significant content of Th.

Alkali-carbonate hydrothermal assemblages similar to those abundant at Kukisvumchorr (with pirssonite and donnayite: Pekov, Podlesnyi, 2004) were unknown (?)until identified at Koashva. In 2006–2009, A.P. Nikolaev found them in the eastern and central parts of the open pit and drill cores. These occurrences are not abundant; their bodies are small in size (as rule, these are pockets do not exceed 0.5 m across), but their mineralogy is diverse and specific. In one case hyperagpaitic assemblages are observed: the major mineral is thermonatrite; burbankite, shortite, pirssonite, villiaumite, rasvumite, and djerfisherite are typical; and sidorenkite, khanneshite, merlinoite, and gцtzenite were found. In other cases these are lower-alkali assemblages where the carbonates in cavities are calcite, strontianite, donnayite-(Y), mckelveyite-(Y), burbankite, and barytocalcite, which are associated with fluorite and natrolite.

Veins of columnar natrolite up to 2–5 cm thick, and sometimes up to 10–20 cm, are abundant in the Koashva open pit, especially in the western and central parts where they cut varied silicate rocks. As rule, these veins are monomineralic without caverns; but in some cases cavities encrusted with prismatic colorless natrolite and containing crystals of calcite up to 5–7 cm in size were found in swells. Among other sporadic minerals in these veins, potassic feldspar and aegirine in selvages, as well as fluorite, fluorapatite, strontianite, ancylite-(Ce), and harmotome should be noted.

Late veinlet Ca-rich hydrothermal assemblages cut all rocks including apatite ores, pegmatites and veins of columnar natrolite. They are distributed in the deposit area and are most abundant in the fault and brecciation zones. This type of low-temperature hydrothermal assemblage, the latest endogenic assemblage in Kihibiny, occurs throughout the apatite-bearing melteigite-urtite complex of the Khibiny massif and was described in detail by Lovaksya *et al*. (2002) and Pekov *et al*. (2004). Predominantly zeolite veins with minor carbonate-apatite, montmorillonite and calcite are typical for Koashva. The members of the natrolite series, thomsonite-Ca, Ca-rich chabazite-K, and phillipsite-K, occur in the veins.

Minerals

The minerals of pegmatites and hydrothermal assemblages of the Koashva deposit are briefly described in this section. The outstanding finds and rare mineral species are focused. We have studied in different detail level 116 of 155 minerals listed in Table 1. 127 minerals are briefly described in this section with only literature data for 11 minerals. We tried to give quantitative chemical data of mineral if they are known; 82 of 119 analyses given in this paper are original data, with 38 analyses being published for the first time. The unit cell dimensions of the minerals obtained with the single-crystal X-ray diffraction data, which were not previously published, are given.

The minerals are reported in the sequence corresponding to conventional chemical classification. Pegmatites and hydrothermal assemblages are dominated by silicates (86 species) followed by carbonates (19), phosphates and sulfides (by 17), oxides (98), fluorides (5), native elements, sulfates, and oxalates (by 1).

Table 1. ***Minerals of Pegmatites and Hydrothermal Assemblages of Koashva***

Minerals	Localities							
	1	2	3	4	5	6	7	8
Native elements								
Graphite*						++		
Sulfides								
Chalcocite				+				
Galena	+	+	+	+	+	+	+	+
Sphalerite*	++	++	++	+	+	++	++	++
Pyrrhotite	+	+						++
Troilite*			+					
Mackinawite*			+				+	+
Covellite*			+					
Molybdenite*			+	+	++		+	+
Pyrite				+				+
Chalcopyrite	+			+				+
Rasvumite*		++	+				+	++
Djerfisherite*		+	+	+		+	++	+
Chlorbartonite*			x			++		+
Murunskite*			+				++	+
Orickite*	+					+		
Wilhelmramsayite*			X					
Cobaltite*	+	+	+				+	
Fluorides								
Villiaumite		+++	+++	+			+++	+++
Fluorite*	+				+	++		++
Strontiofluorite*						x		
Polezhaevaite-(Ce)*						x		
Elpasolite*				+		+		
Oxides								
Brookite								+
Ilmenite*						++		++
Pyrophanite*				+		++		
Magnetite								++
Loparite*		+	+		+		++	+
Lueshite*								+
Lucasite-(Ce)*				+				+
Pyrochlore*					+	+		+
Silicates								
Zircon*						+		
Leucophanite*			+		+			+
Phosinaite-(Ce)								x
Clinophosinaite								x
Steenstrupine-(Ce)*		+	+				++	+
Thorosteenstrupine*		+	+				+	
Diopside (aegirine-salite) *	+++	+++	+++	++	+++	++	++	+++
Aegirine*	+++	+++	+++	+++	+++	+++	+++	+++
Pectolite*	+++	+++	+++	+++	+++	++	+++	+++
Pectolite-*M2abc**					++			+
Aenigmatite								++
Arfvedsonite	+++	+++	+++	+++	+++	+++	+++	+++
Potassic-magnesio-arfvedsonite *	++	++						
Fenaksite								+
Odintsovite*								+
Tiettaite								x
Ershovite								x
Shafranovskite*								+
Phlogopite (including biotite)*			+	+	+	+		+++
Annite			+					+
Tainiolite*						+		
Montmorillonite								++

Table 1. ***(continuation)***

Minerals	Localities							
	1	2	3	4	5	6	7	8
Albite						++		++
Anorthoclase								++
Orthoclase*	+++	+++	+++	+++	+++	+++	+++	+++
Microcline*	+++	+++	+++	+++	+++	+++	+++	+++
Nepheline	+++	+++	+++	++	+++	++	+++	+++
MEGAKALSILITE			x					
Sodalite	+++	+++	+++	+++	+++	++	+++	+++
Cancrinite*								++
Cancrisilite*			++					+
Vishnevite*						+		
CARBOBYSTRITE			x					
Chkalovite		+	++	++			++	++
Analcime								++
LISITSYNITE			x					
Natrolite*	+++	++	++	+++	+++	+++	++	+++
Gonnardite*								++
Paranatrolite*								+
Thomsonite-Ca*								++
Phillipsite-K*								+++
Harmotome*								+
Amicite*				+		+		
Merlinoite*								+
Chabazite-K*								+++
Wadeite*		+			++			++
Catapleiite*	++	+		++	+			++
Georgechaoite*					++			++
Kostylevite*		+			++			
Umbite*		++		+	+			++
Paraumbite*								++
SAZYKINAITE-(Y)*	xx	+		+	++			++
Eudialyte*		++		++				+++
Kentbrooksite*								+
ANDRIANOVITE*					++			x
Labyrinthite								+
ZIRSINALITE								xx
Lovozerite*			+					++
Kazakovite*								+
TISINALITE								x
KOASHVITE								x
Titanite*	++				++	++		+++
Natisite*							++	+
Rinkite*	++	+++	++		++		++	+++
Mosandrite								++
Götzenite*								+
Shcherbakovite*	+		+				+	++
Labuntsovite-Mn*				+		+		++
LEMMLEINITE-K*	xx		+	++				++
Sitinakite*	++			+				++
IVANYUKITE-Na*				x				
IVANYUKITE-K*	+			x				+
IVANYUKITE-Cu*				x				
Lorenzenite*	++		++	++	++	++		++
Vinogradovite*				++		+		
Lamprophyllite*	+++	+++	+++	+++	+++	++	+++	+++
Barytolamprophyllite*	+	+			++	+		+
Astrophyllite*			+	+		+++		++
Kupletskite*								+
Magnesioastrophyllite*	++		++				++	++

Table 1. ***(continuation)***

Minerals	Localities							
	1	2	3	4	5	6	7	8
Lomonosovite*		++	+++				+++	+++
Lomonosovite-beta*								++
Murmanite*	++							++
Vuonnemite								+
Neptunite*								+
Manganoneptunite				+				
Phosphates								
DORFMANITE*			+					**xx**
Natrophosphate*		+	++					++
Vitusite-(Ce)*		++	++				+	++
Monazite-(Ce)								+
Rhabdophane-(Ce)*	++				+			+
Nacaphite*		++	++				++	
Nefedovite*			++				++	
Arctite*	+							
Fluorapatite*	++	+++	++	++	+++	++	++	+++
Hydroxylapatite						+		
FLUORCAPHITE*	++		++	++			++	**xx**
Fluorstrophite*		+						
Belovite-(Ce)*	++		+					++
DELONEITE								**x**
Sidorenkite*		+	+					+
Bonshtedtite			+					
CRAWFORDITE								**x**
Carbonates								
Natrite*			+++				+++	++
Thermonatrite*		++	+++				+++	+++
Natron*								++
Trona			+					
Calcite								++
Strontianite*					+			++
Barytocalcite*								+
Shortite*								++
Burbankite*			+			++		++
Khanneshite*								+
Remondite-(Ce)*								+
REMONDITE-(La)*								**x**
Petersenite-(Ce)*		+						
Pirssonite*								+
Ancylite-(Ce)*					++			+
Ancylite-(La)*								+
Donnayite-(Y)*								+
Mckelveyite-(Y)*								+
Malachite*	+							
Sulfates								
Brochantite*				+				
Oxalates								
Natroxalate*			+					

Notes: Number of column means (1–7) pegmatite bodies:
(1) Sazykinaitovoe, (2) Umbitovoe, (3) Koashva-99, (4) Koashva-2005, (5) Koashva-2007/1, (6) Koashva-2007/2, (7) Koashva-2008; (8) other pegmatite and hydrothermal bodies of Koashva, see text for explanation.
(+++) Abundant minerals;
(++) Less-common minerals;
(+) Rare minerals.
THE MINERAL DISCOVERED AT KOASHVA are capitalized and bolded. **xx** and **x** denote type locality:
(**xx**) less-common and (**x**) rare mineral. Published data and author's original materials have been used in the table.
(*) denotes that the mineral was studied by the authors or with their participation.

57. Late **orthoclase** pseudomorph after radial aggregates (up to 5 mm) of natrolite(?) long-prismatic crystals in cavity of a zeolite veinlet.
Collection: A.P. Nikolaev.
Photo: S.I. Pekov.

58. Cluster of **microcline** crystals (up to 1.6 cm) colored crimson red by **villiaumite** small inclusions.
Koashva-99 pegmatite.
Collection: A.P. Nikolaev.
Photo: S.I. Pekov.

Phlogopite, $KMg_3[AlSi_3O_{10}](OH)_2$, with insignificant admixture of Fe, was found in the core of the Koashva-2005 pegmatite as brown small (a few mm) hexagonal prismatic divergent crystals with natrolite, pectolite, and fluorcaphite. A.P. Khomyakov has identified crystals of phlogopite about 1 mm in size enclosed together with nacaphite in aggregates of natrite and thermonatrite in the Koashva-99 pegmatite. The X-ray diffraction study revealed that they belong to different polytypes: one of them was phlogopite-1*M*, while another was orthorhombic phlogopite-2*O* that was not previously known in nature (Ferraris *et al.*, 2001). Biotite with variable Fe/(Fe+Mg) value is a typical mineral of simple pegmatites.

Tainiolite, $KMg_2Li[Si_4O_{10}]F_2$, has been found by I.V. Pekov in the Koashva-2007/2 pegmatite. It occurs as hexagonal tabular, short-prismatic or more frequently terminated hexagonal pyramid in shape (widened toward the top) crystals up to 1.5 cm in length and radial or chaotic integrowths of these crystals. They are embedded in natrolite or occur in the cavities in association with aegirine, astrophyllite, lorenzenite, chlorbartonite, apatite, burbankite, polezhaevaite-(Ce), strontiofluorite, minerals of the ilmenite-pyrophanite series, and sphalerite. This mica is brownish gray with strong nacreous luster.

Potassic feldspars, $K[AlSi_3O_8]$, are **orthoclase** and **microcline** in the Koashva pegmatites. Orthoclase is typical of simple pegmatites (where its light green blocks up to 20 cm with aqua-transparent areas are observed) and margins of differentiated bodies. Microcline including white, gray or greenish well-shaped prismatic and tabular crystals up to 10–15 cm is predominant in the cores of zoned pegmatites. Sometimes they are mottled owing to abundant microinclusions: areas enriched in aegirine and villiaumite are bright green and red (fig. 58), respectively. High-ordered, so called maximum microcline as white or beige crusts, small druses, and fine-grained aggregates together with natrolite occurs in the latest assemblages of the cavities. Late low-temperature orthoclase (fig. 57) is found in the cavities of zeolite veinlets.

59. **Nepheline** crystal in sugar-like fluorapatite. 2 cm.
Collection: I.V. Pekov, #7493.
Photo: S.I. Pekov.

Nepheline, $(Na,K)[AlSiO_4]$, is one of the major minerals of simple pegmatites and early assemblages (marginal zones) of differentiated pegmatites. It is absent in the cores of zoned pegmatites and hydrothermal assemblages of various types. Well-shaped greenish gray crystals of nepheline up to 3 cm as shortened hexagonal prisms with flat hemihedral terminations frozen in light green fluorapatite (fig. 59) are identified at the contact of simple pegmatites and apatite-nepheline ores.

Table 7. ***Chemical composition (wt. %) of aluminosilicates and borosilicate from pegmatites and hydrothermal assemblages of Koashva***

Number	1	2	3	4	5	6	7	8	9	10	11	12	13
Sample		Ko-1652	Ko-240	Ko-2646	Ko-2677			Ko-1266	Ko-493	Ko-1239	Ko-2198	Ko-2853	Ko-4к
Na_2O	0.02	21.31	21.92	22.86	13.65	22.66		14.86	8.77	0.30	8.89	0.37	0.96
K_2O	29.73	–	0.07	0.51	14.50	1.75	23.50	0.08	2.26	0.85	13.85	21.22	9.03
CaO		3.25	0.33	0.45	–			–	0.25	3.16	–	0.08	5.43
SrO		–	–	–	–			0.10	–	1.92	–	–	4.16
BaO		–	–	–	–			–	0.10	23.52	–	–	0.11
MgO		–	–	–	–			0.01	0.05	–	–	–	0.02
Al_2O_3	32.38	28.12	25.50	25.88	27.82	30.42		26.96	29.57	22.42	29.73	22.96	20.76
Fe_2O_3	0.04	–	0.13	0.40	0.73			–	0.02	–	–	0.59	0.13
SiO_2	37.96	38.31	41.70	41.52	33.23	35.42	58.94	49.88	45.89	30.84	33.84	41.58	45.74
SO_3		–	0.06	–	7.36			–	–	–	–	–	–
Total	100.14*	91.00	89.82*	91.61	97.28	101.20*	99.61*	91.89	86.91	83.01	86.31	86.80	86.34

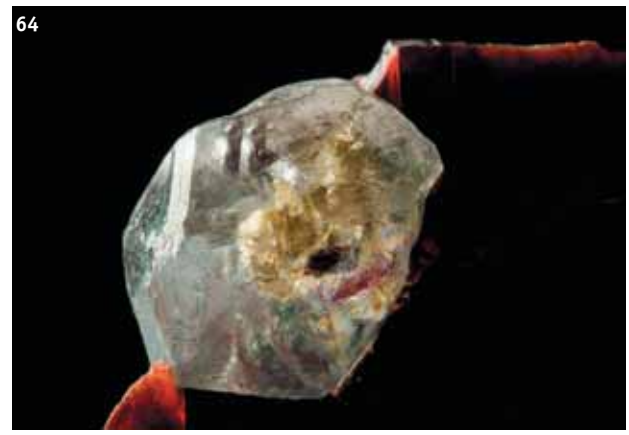
Notes: (1) megakalsilite, (2) cancrinite, (3–4) cancrisilite, (5) vishnevite, (6) carbobystrite, (7) lisitsynite, (8) natrolite, (9) paranatrolite, (10) harmotome, (11) amicite, (12) merlinoite, (13) chabazite-K. Locality: (1, 4, 6, 7) Koashva-99; (2) hyperagpaitic veinlet in the southwestern field; (3) Koashva-96; (5) Koashva-2007/2; (8) Sazykinaitovoe; (9, 10, 13) zeolite veinlets uncovered by the Koashva open pit; (11) Koashva-2005; (12) hyperagpaitic pegmatite in the eastern part of the open pit. Source: (1) Khomyakov *et al.* (2002); (2, 4, 5) Olysych (2010); (3) Pekov *et al.* (2000b); (6) Khomyakov *et al.* (2010); (7) Khomyakov *et al.* (2000); (8–10, 13); Pekov *et al.* (2004); this study for the others.
(*) Total includes 0.01 TiO_2 (# 1); 0.06 Cl and -0.01 -O=Cl_2 in # 3; 4.37 CO_2 and 6.26 H_2O (calculated values) in # 6; and 17.17 B_2O_3 (# 7).

63. **Chkalovite** crystal (1.2 cm) in **villiaumite**. Koashva-2008 pegmatite. Collection: I.V. Pekov, #8632. Photo: M.B. Leybov.

64. **Chkalovite** crystal (1.3 cm) with yellow inclusions of **magnesioastrophyllite** in dark red **villiaumite**. Koashva-2008 pegmatite. Collection: A.P. Nikolaev. Photo: S.I. Pekov.

Carbobystrite, $Na_8[Al_6Si_6O_{24}](CO_3)•4H_2O$, was described as a new mineral from the Koashva-99 pegmatite by Khomyakov *et al.* (2010) on the material collected by A.P. Nikolaev. It was found in the hyperagpaitic core of this pegmatite as colorless transparent grain of 3 mm in size intergrown with sodalite, natrite, and megakalsilite (Khomyakov *et al.*, 2010).

Chkalovite, $Na_2[BeSi_2O_6]$, is a typical mineral of hyperagpaitic pegmatites of the southwestern (main) field and is the major concentrator of Be in these pegmatites.



69. **Natrolite** crystal cluster colored greenish with aegirine microinclusions. 2.5 cm. Koashva-2005 pegmatite. Collection: I.V. Pekov, #2695. Photo: S.I. Pekov.

70. **Natrolite** crystal cluster. 4.5 cm. Koashva-2005 pegmatite. Collection: I.V. Pekov, #2618. Photo: M.B. Leybov.

71. Parallel intergrowth of **natrolite** crystals. 9 cm. Koashva-2005 pegmatite. Collection: I.V. Pekov, #2626. Photo: M.B. Leybov.

green aegirine and pectolite. In these cavities, natrolite is associated with vinogradovite, lemmleinite-K, ivanyukite-Na, and catapleiite.

Gonnardite, $(Na,Ca,K)_{6-8}[(Si,Al)_{20}O_{40}]\bullet 12H_2O$, presented by tetranatrolite, a Ca-poor variety, is common in the late zeolite veinlets, where it forms white columnar aggregates. It is found in small amount in the cavities of differentiated pegmatites, where it occasionally overgrows aegirine or pectolite as colorless of white bar-shaped crystals, which are divergent sometimes to form spectacular spherical crystals up to 0.5 cm in size (fig. 72).

Paranatrolite, $Na_2K_{0.25}[Al_{2.25}Si_{2.75}O_{10}]\bullet 3H_2O$ is occasional in hyperagpaitic pegmatites, where it forms colorless divergent prismatic crystals up to 2–3 mm, which quickly become white in dry air, and spherulitic crusts coating walls of small cavities (Pekov *et al.*, 2004).

Phillipsite-K, $(K,Ca_{0.5},Na,Ba_{0.5})_{4-7}[Al_{4-7}Si_{12-9}O_{32}]\bullet 12H_2O$, is one of the most abundant zeolites in the late hydrothermal veinlets (Lovskaya *et al.*, 2002). It coats, usually together with chabazite-K, walls of open cavities in these veinlets overgrowing natrolite, gonnardite, thomsonite-Ca. Phillipsite-K occurs as colorless transparent well-formed crystals and twins (fourlings) up to 1 mm.

Harmotome, $(Ba_{0.5},K,Na,Ca_{0.5})_5[Al_5Si_{11}O_{32}]\bullet 12H_2O$, was found in one of the natrolite veinlets. Its white aggregates of rough-shaped crystals (up to 1 mm) with yellowish ancylite-(Ce) are in the cavities of dissolved hexagonal prisms of unknown minerals (Pekov *et al.*, 2004).

Amicite, $K_4Na_4[Al_8Si_8O_{32}]\bullet 10H_2O$, was found by I.V. Pekov in the natrolite cores of the Koashva-2005 and Koashva-2007/2 pegmatites. In the both cases, it forms colorless transparent well-shaped crystals (up to 3 mm) as rectangular bipyramids, which overgrow natrolite in the small cavities and is intimately associated with elpasolite. In the Koashva-2007/2 pegmatite, acicular vishnevite occurs in the same cavities. The unit cell dimensions of amicite from the Koashva-2005 pegmatite (triclinic aspect) are $a = 8.695(12)$, $b = 8.722(18)$, $c = 8.883(19)$ Å, $\alpha = 109.0(2)\equiv$, $\beta = 111.92(16)\equiv$, $\gamma = 106.58(16)\equiv$.

Merlinoite, $(K,Na,Ca_{0.5})_{7-12}[Al_{9-12}Si_{23-20}O_{64}]\bullet 20\text{-}24H_2O$, was found in 2008 in the small peralkaline pegmatite at the level +100 m in eastern part of the open pit. Its

brown and greenish yellow long-prismatic crystals up to 20 cm long usually combined into radial intergrowths. It alters to mosandrite under hydrothermal conditions. Sometimes, rinkite including its Nb-rich variety (Pekov *et al.*, 2000a) occurs in the cores of hyperagpaitic pegmatites, where bunches and near-parallel aggregates of its columnar crystals (fig. 94) reaching 10 cm in length are embedded in the pockets of villiaumite and soda carbonates.

Götzenite, $Na_4Ca_{10}Ti_2(Si_2O_7)_4F_8$, was found at Koashva in 2008. A.P. Nikolaev collected a sample with this mineral from a small hyperagpaitic pegmatoid body in eastern part of the open pit. Götzenite occurs as sheaf-like intergrowths of white prismatic crystals up to 7 mm in length with yellow luminescence in SW UV light. They were found, together with pectolite, burbankite, khanneshite, gonnardite and calcite, on the walls of small cavity filled by thermonatrite in feldspar-aegirine rock. The triclinic unit cell dimensions are: $a = 9.620(9)$, $b = 7.306(6)$, $c = 5.744(5)$ Å, $\alpha = 90.11(7)$≡, $\beta = 101.13(8)$≡, $\gamma = 100.99(8)$≡.

Shcherbakovite, $NaK(K,Ba)(Ti,Nb)_2Si_4O_{14}$, has been identified in hyperagpaitic assemblages of a few differentiated pegmatites of Koashva. For example, we found the Nb-rich variety of this mineral as brown fine (up to 1 mm) well-shaped prismatic crystals embedded in sodalite in the Koashva-2008 pegmatite, whereas relatively Nb-poor variety together with lorenzenite forms radial intergrowths up to 4 mm in diameter in sodalite of the intermediate zone of the Koashva-99 pegmatite (Yakovenchuk *et al.*, 2005). The best specimens of shcherbakovite came from the Shcherbakovitovoe pegmatite, which is the uppermost of the large differentiated bodies forming the southwestern pegmatite field. These are brown lustrous perfect prismatic crystals up to 0.5 x 5 cm with well-formed terminations (fig. 95) embedded in sodalite and natrolite together with aegirine and pectolite. Here, Yakovenchuk *et al.* (2005) reported knee-like twins of shcherbakovite on (110).

Labuntsovite-Mn, $Na_2K_2Mn_{1-x}Ti_4(Si_4O_{12})_2(O,OH)_4 \bullet 6H_2O$, was found in a small amount in a few hydrothermally altered pegmatite bodies. For example, its thick-tabular (flattened along [010]) crystals up to 0.5 mm replace murmanite in the small cavity in the simple pegmatite with hyperagpaitic pockets (Chukanov *et al.*, 2003). In the Koashva-2007/2 pegmatite, yellow tiny crystals of labuntsovite-Mn overgrow natrolite. In all cases at Koashva, this mineral is represented by the K-rich variety transitional to lemmleinite-K in composition.

Lemmleinite-K, $Na_2K_4Ti_4(Si_4O_{12})_2(OH,O)_4 \bullet 4H_2O$, was described as a new mineral by Khomyakov *et al.* (1999) from the Sazykinaitovoe pegmatite. Mostly aegirine zone of this pegmatite with minor alkali amphibole, potassic feldspar, natrolite, pectolite, lamprophyllite, altered lomonosovite, and sphalerite contains abundant cavities, whose walls are coated by the crystals of lemmleinite-K (up to 1 mm), sazykinaite-(Y), catapleiite, and aggregates of K-bearing rhabdophane-(Ce). The crystals of lemmleinite-K are flattened bipyramids that is uncommon for the labuntsovite-group min-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94. Yellowish long-prismatic **rinkite** crystals (up to 0.7 cm long) in cavity of pectolite-natrolite aggregate with aegirine. Collection: A.V. Kasatkin. Photo: M.B. Leybov.
95. Intergrowth of prismatic brown **shcherbakovite** crystals (largest is 2.8 cm) and **magnesioastrophyllite** spherulites on microcline. Shcherbakovitovoe pegmatite. Collection: A.V.Kasatkin. Photo: M.B. Leybov.

108. **Magnesioastrophyllite** spherulite with **loparite** black twins. Koashva-99 pegmatite. Collection: I.V. Pekov, #7467. Photo: I.V. Pekov and A.V. Kasatkin.

ored lamellar of flattened-prismatic (sometimes as well-shaped crystals up to 1 mm) and light goldish yellow acicular (fig. 108). In the Shcherbakovitovoe and Sazykinaitovoe pegmatites, the first variety forms compact spherical and cone-shaped clusters up to 2 cm across, which are embedded in natrolite or occur in the cavities, while dense "balls" (up to 1 cm) of the second variety are typical for the Koashva-99 pegmatite.

Lomonosovite, $Na_2Ti_2Si_2O_9 \bullet Na_3PO_4$, is abundant in the alkali-richest assemblages of the Koashva pegmatites and is reliable indicator of hyperagpaitic conditions of mineral formation. Altered lomonosovite (sometimes with relicts of fresh phase) transformed to the aggregates of various titanosilicates, namely murmanite, vinogradovite, sitinakite, labuntsovite- and lamprophyllite-group members, and ivanyukite-series members, is usual in hydrothermally altered simple pegmatites without "salinet" mineralization; sometimes, loparite replaces lomonosovite (the Koashva-2008 pegmatite). The best specimens of lomonosovite come from the Umbitovoe, Koashva-99, and Koashva-2008 pegmatites, where its large (up to 0.5 cm) well-shaped lustrous dark brown to nearly black lamellar crystals, sometimes curved and divergent, occurr in villiaumite, natrite, or thermonatrite pockets. The most spectacular specimens of lomonosovite from the Koashva-99 and Koashva-2008 pegmatites are the crystals and twins (recognized by the striation on the major faces {001}) sometimes associated with chkalovite, fluorcaphite, and pectolite, which are embedded in red coarse-blocky villiaumite (fig. 110) or white aggregates of soda carbonates. Here, roughly-formed lamellar individuals of lomonosovite reach 14 cm across and frequently form radial or chaotic intergrowths. In the Umbitovoe pegmatite, rectangular lamellas of lomonosovite overgrow crystals of microcline (fig. 109) and aggregates of acicular aegirine; specimens with these minerals were recovered from the cavities after dissolution of villiaumite and thermonatrite.

Lomonosovite-beta, $Na_4Ti_4Si_4O_{18} \bullet Na_3[PO_3(OH)PO_2(OH)_2]$, at Koshva was noted by Khomyakov (Khomyakov, 1995), who did not describe this mineral, but published its chemical analysis. We have studied in detail lomonosovite-beta from the Shcherbakovitovoe pegmatite, where it is present two varieties: light yellow rectangular lamellae up to 2 cm occur in the intermediate zone (where they are replaced by lilac murmanite) together with aegirine, microcline, lamprophyllite, and pectolite, while pale pink lamellae up to 0.5 cm slightly depleted in Na are typical for the natrolitized core with shcherbakovite.

Murmanite, $Na_2Ti_2Si_2O_9 \bullet nH_2O$, is a product of late hydrothermal alteration of lomonosovite in hyperagpaitic pegmatites. Its brownish, gray, or pale lilac homo-axial pseudomorphs after lomonosovite have been found in Sazykinaitovoe and some other bodies. The spectacular bright

109. **Lomonosovite** tabular crystal on cube-like **microcline** crystal with abundant aegirine micro-inclusions. 1.7 cm. Umbitovoe pegmatite. Collection: I.V. Pekov, #7486. Photo: N.A. Pekova.

110. **Lomonosovite** tabular crystal in villiaumite. 3 cm. Koashva-2008 pegmatite. Collection: A.P. Nikolaev. Photo: B.Z. Kantor.

127. Orange-yellow **remondite-(La)** on brown **cancrisilite** (with white powdered thermonatrite efflorescence). Koashva-96 pegmatite. Collection: I.V. Pekov, #9566. Photo: I.V. Pekov and A.V. Kasatkin.

128. White sheaf-like split long-prismatic crystals of **ancylite-(Ce)** on natrolite with lamprophyllite. Koashva-2007/1 pegmatite. Collection: I.V. Pekov, #4945. Photo: I.V. Pekov and A.V. Kasatkin.

strontianite, burbankite, barytocalcite, fluorite, molybdenite, sodalite, calcite, and natrolite in a cavity. The mineral shows a weak orange luminescence in SW UV light.

***Oxalates** are presented at Koashva by* **natroxalate**, $Na_2C_2O_4$ *that has been found by A.P. Nikolaev in the core of the Koashva-99 pegmatite and determined by A.P. Khomyakov. This is the only colorless transparent prismatic crystal of 0.3 x 1.5 cm in size embedded in the aggregate of thermonatrite and villiaumite.*

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