MINERALOGY OF THE GLUBOSTROVSKOYE OCCURRENCE OF MASUTOMILITE ON THE SOUTHERN URALS

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Glubostrovskoye occurrence is a granite pegmatite with large plates of masutomilite and Li-containing muscovite. Topaz, beryl, manganocolumbite, cassiterite, monazite-(Ce), microlite and other accessory minerals also occure there. The structure of the pegmatite is characterized and the data on the morphology and chemical composition of minerals are resulted. The following concentrations of elements are determined in violet and pinkish-violet ferroan masutomilite (crystals are up to 5 – 20 cm in size) (wt.%): MnO 5.85; Li_2O 3.98; Rb_2O 1.67. Late pinkish beryl is enriched with rare alkalis, monazite-(Ce) – with samarium, zircon – with hafnium. In microlite we have found partial pseudomorphoses of parabariomicrolite on it. These pseudomorphoses contain the following elements (wt.%): BaO 10.10; UO_2 4.98; Ta_2O_5 73.60; Nb_2O_5 5.49; SnO_2 2.74. It is the first finding in the Urals and in Russia.
7 tables, 10 figures, 11 references.
Keywords: masutomilite, topaz, beryl, microlite, parabariomicrolite, Glubostrovskoye occurrence, Southern Urals.

History of discovery and geological structure of the Glubostrovskoye occurrence

Glubostrovskoye occurrence of lithium (lepidolite) was accidentally discovered in 5 km to the north-west from the Tayginka settlement, on the ridge of the Zayachiy mountains, in the boggy intermountain lowland in 200 m to the north from the coast of the Glubostrovo lake (Fig. 1). In 1956, pegmatite vein was discovered during laying of electric transmission facility in a hole dug for a support. During hunting in the late autumn when the bog has frozen slightly, geologist D.P. Groznetsky has found out large plates of lepidolite in the pegmatite blocks. Next year Slyudianogorsky party of the "Uralgeolnerud" trust drilled 40 drill holes of hand boring ("Empire" drill) to the depth up to 1 – 5 m in the peat layer, up to blocks and crumbs of rocks, on the Glubostrovskoye occurrence. During winter of 1958, Ilmenogorsky party of the Expedition No. 8 dug 40 bore pits to the depth up to 1.5 m (with soil freezing). During summer of 1958, survey-and-research works of the scale 1:10000 on the area of about 2 square km (Talantsev, 1959) was carried out. Results of the works appeared to be unfavourable: concentration of lithium in lepidolite reached up to 5.6 wt.% Li_2O, but in samples of the pegmatite its content was very low (0 – 0.5 wt.% Li_2O); small sizes of the vein and marshiness of the site were adverse to exploitation of the occurrence. The vein has been left, and we do not know the published works concerning its mineralogy. The mentioning about the Glubostrovskoye occurrence of lithium is in 12-th volume of "Geology of the USSR" (1973), in the table of deposits and occurrences of precious and semiprecious stones of the Urals. Still then 14-years old S.V. Kolisnichenko has bought this book in Leningrad. But only in 1980 with a group of young geologists he could try to find the vein not knowing that it was in a bog. They have not found the vein. Only in autumn of 2008, shovelman Vasily Lezhnev from the Tayginka settlement – the amateur of minerals and the hunter – has accidentally discovered blocks of pegmatite with violet leaflets of mica. In 2009 he showed us this place. But it was impossible to conduct works in this place because of the presence of water. In dry summer of 2010 we had this opportunity; the water level fell almost one meter down. The history of this finding is briefly published (Kolisnichenko, Zakharov, 2010). Some times in that summer we carried out stripping work (with assistants – I.V. Karlov, A.V. Bobrov, T.M. Rakhmatullin, K.A. Zaharov, R.M. Rakhmatullin, D.A. Shumilin, A.G. Korablyov, and E.P. Makagonov) on the vein. On the place of two old bore pits one small mine has been engaged, a number of old bore bits has been cleared away and two new ones has been worked, dumps of the old bore pits have been partly reviewed and a number slimes has been received. The marshland has not allowed revealing completely the sizes, the form and the structure of the vein. But the data received appeared to be extremely interesting and are given below (we also use materials on the geology of the site).

According to the data of A.S. Talantsev (1959), the northern part of the ridge of the Zayachiy mountains represents submeridional anticlinal fold, overthrown to the west (see Fig. 1). The axial part of the structure consists of the Lower Proterozoic metamorphic biotite-

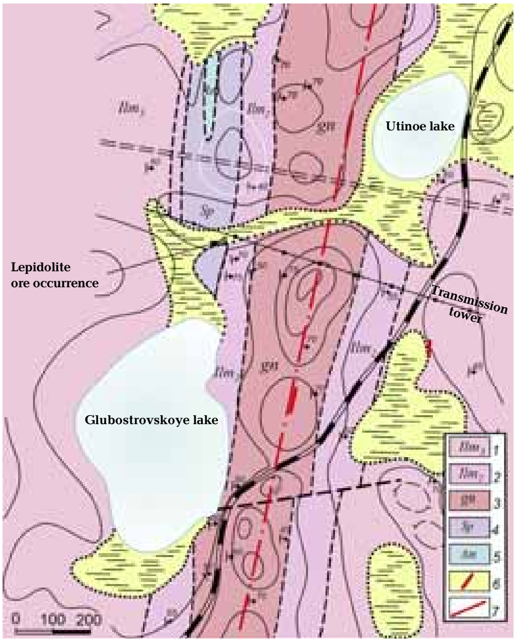


Fig. 1. Geological map of the northern part the Zayachiy ridge (according to Talantsev, 1959; simplified).
1 — amphibolites with biotite quartzite-gneisses layers; 2 — biotite gneisses with layers of amphibolites; 3 — microcline gneisses with orthite (allanite); 4 — serpentinites; 5 — amphibolites; 6 — granite pegmatites; 7 — tectonic fault. Glubostrovskoye occurrence of lithium micas is specified by an arrow.

microcline gneisses of the Vishnevogorsky series with orthite and magnetite, and its wings from the west and from the east consist of alternating amphibolites, biotitic gneisses and quartzites of the Ilmenogorsky series. The ultrabasic rocks have been attributed by him to peridotites (according to our data, these rocks are olivine—enstatite orthopyroxenites with 15—20% of olivine), serpentinized, talked and amphibolized in a different degree and containing fine-grained dissemination of magnetite and chromite. Serpentinized ultrabasic rocks are surrounded by amphibolic rocks and include rare vein bodies of plagioclasites with a rim of radiate-lamellar tremolite (for example, in 100 m to the north-west from the Glubostrovskaya vein). All rocks are intersected by more young sublatitudinal faults of a wrench fault type (according to the form of lowlands we assume also presence of submeridional faults and faults of north-western directions). Several veins of granite pegmatites containing topaz and beryl (one them containing amazonite) are known in the axial part of the Zayachiy ridge (they are not examined in this article).

Glubostrovskaya vein of granite pegmatite was proven according to the data of hand boring. Its form appeared to be a drop-shaped body with prospective northeast strike. It was specified, that such form can be deformed, and the size of the vein can be overestimated owing to the vein's disruption (Talantsev, 1959), and northeast and southwest "tails" of the vein have not been confirmed. The following zones were allocated in its structure: marginal — fine-grained zone of aplitic pegmatite with chlorite and garnet (according to our data, the zone is not clearly graphical with gradual transition to graphical); intermediate zones — graphical and block, without sharp borders; and central zone with development of cleavelandite and lepidolite, considered as result of the replacement of a microcline belonging to the block zone (Fig. 2a).

As a result of our works on clearing of some accessible bore pits, driving of new open pits and survey of the occurrence's area by hand probe on about a meter depth it appeared, that pegmatite vein had another sizes, form, structure, and bedding (Fig. 2b). Its probable extent was more than 25 meters at the maximal seen thickness of about 10 m and southwest dip. The northern part of the vein is appeared to be intersected by a fault or eroded by ancient water streams of the former small river channel on a place of the present bog. Because of a thick layer of peat in the vein's environment (up to 4—5 m) its host rocks were not established authentically and were shown on the vein's structure map as serpentinites. However we have taken a fine crumb of grains and aggregates of Na-Ca amphiboles (more characteristic for amphibolites or gneisses) from bottoms of some bore pits situated outside the vein.

Zones of the pegmatite on their structure basically were similar to those allocated earlier with that only a difference that block zone was much smaller, and aggregates of lepidolite with albite, topaz, beryl, and accessory minerals were mainly located in it. The part of its quartz nucleus was also opened in its northeast wall.

Works of the Ilmenogorsky party on this site practically were not accompanied by analytical researches (except for definition of contents of lithium and beryllium). In their report the following minerals composing the vein (according to their external attributes) have been briefly mentioned: microcline-perthite, albite, quartz, muscovite, topaz, lepidolite, zinnwaldite, fluorite, chlorite, and garnet.

But the first stripping works of 2010 have surprised with a finding of large violet plates of lepidolite (up to 10—20 cm in diameter), "co-

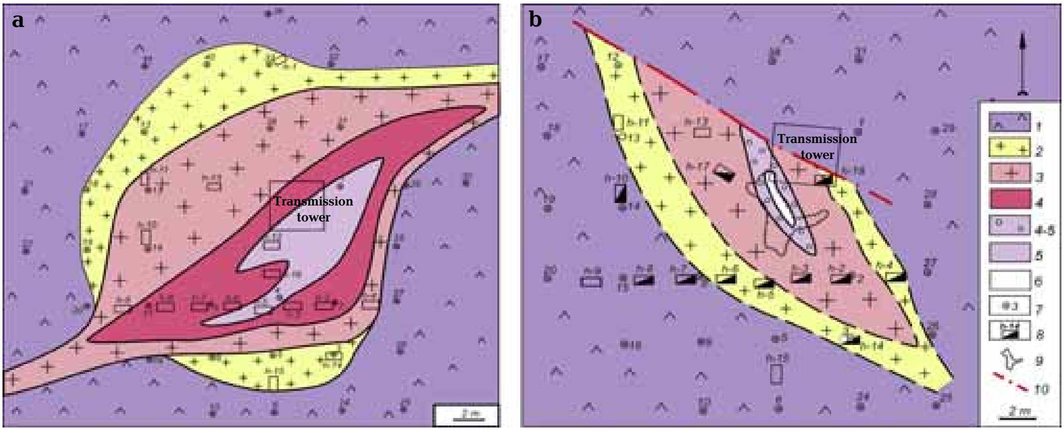


Fig. 2. The scheme of zonality of the pegmatite (a — according to Talantsev, 1959; b — our data).
1 — host rocks — "serpentinites" (gneisses, more probable); 2 — medium-grained not clearly graphic quartz-oligoclase-microcline pegmatite with siderophyllite, passing into small-block large-graphic pegmatite; 3 — graphic quartz-microcline pegmatite with muscovite; 4 — «central pegmatoid block» (a; according to Talantsev, 1959); 4—5 — block zone with masutomilite; 6 — quartz nucleus; 7 — bore holes of hand drilling; 8 — bore pits (cleaned are underlined); 9 — mine contour; 10 — prospective fault.

lumns" of translucent bluish and grayish-white topaz (up to 5 — 20 cm), spessartine, columbite, and also green-yellowish and pinkish beryls (Kolisnichenko, Zakharov, 2010). According to further researches, lepidolite has been determined as masutomilite, and according to studying of pegmatite samples and slices (from the vein's crumb), oligoclase, manganocolumbite, monazite-(Ce), cassiterite, microlite, parabariomicrolite, zircon, Ca- and Mn-containing almandines, allanite-(Ce), siderophyllite (chlorite and fluorite were not found) have been revealed. In slices from a crumb of host rocks from bottoms of bore pits situated outside the vein in addition to earlier specified minerals ferroactinolite, hastingsite, magnesiohornblendite, Fe-containing diopside, epidote, magnetite, ilmenite, and chalcopyrite (diagnosed on physical properties, X-ray diffraction patterns and partial microprobe analyses) were determined.

Microcline and quartz prevail in peripheral medium-grained not clearly graphical zone of the pegmatite with a thickness of no more than 1 m (with gradual transition to a large-graphical small-block zone). Oligoclase of No. 12—15 is less revealed, Ca-containing almandine, siderophyllite, limonitized magnetite occur more seldom, pyrite grains in the form of cubes up to 1 — 1.5 mm in size and also black-brown allanite-(Ce) almost totally replaced by microgranular aggregate of presumably nontronite and hisingerite occur as rare grains. Rare bar-like grains of siderophyllite up to 2 — 3 cm in size and allanite-(Ce) up to 1.5 cm in size (also Mn-containing almandine and translucent yellow-brownish zircon of a "hyacinth" facet in the form of sheaf-like joints up to 2 — 3 mm) occur in the large-graphical pegmatite zone.

Graphical quartz-microcline pegmatite composes the main volume of an opened part of the vein. The width of this zone is about 1 — 2 m. Large blocks of white and yellowish-white feldspar more than 10 — 20 cm in size represent a typical "Jewish" stone with various patterns of quartz ingrowths in sectors of growth of different microcline facets containing about 5 — 8% of albite ingrowths. Small allocations of aggregates of twinned albite grains up to 1 — 2 cm in size, plates of grey muscovite (sometimes having surfaces of joint growth with quartz, microcline, albite and Mn-containing almandine), and also fine grains of the following accessory minerals — manganocolumbite, magnetite, zircon, monazite-(Ce) — occur in the vein's zone. The quantity of albite and size of quartz grains, pinkish-grey muscovite and spessartine gradually increases in this zone in the direction to the center of the vein.

Transition to the block zone is indistinct and also is insufficiently opened because of the mining-and-technical conditions. The zone begins with a rather narrow "strip" (10 — 15 cm) with an abundance of thick-platy pinkish-green-gray muscovite, quartz and split cleavelandite, with original branches-veins in the graphical zone reflecting a dynamic regime existing during the formation of the vein. In one of big samples with grayish (sometimes translucent microcline), albite, spessartine, manganocolumbite, and monazite-(Ce) occur grains of green-yellowish beryl (up to 3 — 6 cm in size), and also a bluish translucent topaz 1 – 2 cm in size (of polygonal-conic form) as a result of co-crystallization with feldspars and quartz. Aggregate of muscovite with albite, quartz, and microcline passes in large – and not clearly graphical small-block zone forming an original subzone (with a width of about 20 – 30 cm) with prevalence of albite and quartz and rather well development of large thick plates of pinkish-violet (lilac) masutomilite up to 5 – 20 cm in diameter and polygonal-conic grains of grayish- or bluish-white topaz (up to 10 – 20 cm in length) partly replaced by the fine-grained aggregate of dark-violet Mn-containing muscovite. Some small grains of topaz are replaced totally with preservation of their primary form.

The subsequent subzone 10 – 15 cm in width is formed by the medium-grained albite aggregate, light-colored pinkish-violet muscovite (grains of 0.5 – 1.5 cm in size), adularia-like microcline and almost colorless quartz. We also meet here isometric-platy grains of manganocolumbite and cavities of dissolution on a place of some mineral with compound-twisting borders. In these transitive subzones the most interesting accessory mineralization is also concentrated.

Typical large-block quartz-microcline pegmatite with a thickness not less than 1 m with rare albite and mica is stripped only partly, as well as its quartz nucleus. Huge in size crystals of microcline (up to 30 – 40 cm) have induction surfaces of joint growth with rare small blocks of light grey quartz. In the extracted pieces of quartz there are many healed cracks. We also meet here sites of small drusy cavities where on crystals of transparent grayish quartz from below there is a thin white peripheral zone, and on the top facets there is a powder of rosette-like fine-grained aggregates of pale lilac and pinkish-yellowish mica-"foamy". This mica overgrows also on fragments of microcline grains in the form of dense crustified aggregates with formation of residual microcavities in which fine prismatic crystals of colorless transparent quartz with rhombohedron facets on "head" crystallized later. The same quartz sometimes also occurs on walls of cavities in places of dissolution of subisometric grains of unstated mineral (possibly fluorite, but we have not found relicts).

Methods and results of investigation of pegmatite minerals and host rocks minerals

A number of minerals are crystallomorphologically characterized (we use Fedorov table SF-4 as a goniometer; idealized crystal forms are drawn with the help of the program SHAPE-7.1 and CorelDRAW-11). Some minerals are investigated optically (in immersion with a set of standard liquids ИЖ-1) and in reflected light on the microscope Olympus BX51. X-ray diffraction patterns of minerals are obtained on X-ray diffractometere DRON-2.0, Cu$K\alpha$-radiation, speed of record 0.02°/min, powder pattern are obtained on URS-2.0 with RKD-57.3 mm, Fe-radiation and are identified on the ASTM base with the control of prevalence of heavy elements in their structure by X-ray fluorescence analysis on the device INNOV. The fluorescence spectrum of a powder of different beryls is obtained on the pulse cathodoluminescence analyzer KLAVI-R. For the following minerals: siderophyllite, oligoclase and allanite-(Ce) the spectra of prevailing elements in their structure (REMMA-202M) are received. The chemical composition of minerals is determined in the Institute of mineralogy of the Russian Academy of Sciences, Urals Branch (Miass) by silicate analysis; rare alkalis are determined by atomic absorption analysis (Perkin-Elmer 3110). X-ray microprobe analysis is executed by V.A. Muftakhov in the Fersman Mineralogical Museum of the Russian Academy of Sciences (Moscow) on the X-ray microanalyzer JEOL-733 Superprobe with energy dispersive spectrometer LINK, operated at 20 кV, absorbed current at 5 nA and beam diameter of 2 microns. Standards are as follows: quartz, albite, orthoclase, diopside, barite, ilmenite, scheelite, fluorapatite, chlorapatite; metals: Mn, Ta, Nb; oxides of Zr, Sn, U, Th, Sb, Y, Dy; phosphate glasses: LaP_5O_{14}, CeP_5O_{14}, PrP_5O_{14}, NdP_5O_{14}, SmP_5O_{14}.

Potassium feldspar from the graphic pegmatite, according to its ordering may be attributed to an intermediate microcline with a 0.8 degree of X-ray triclinity and contains about 5 – 6 mol.% Na-phase. In the block zone of pegmatite, microcline is close to the maximal that is typical to the majority of granite pegmatite veins.

Among the micas from the Glubostrovskaya vein, muscovite and masutomilite are most widespread, and siderophyllite and illite are rare.

Siderophyllite is a black mica of the marginal zone of the vein. It is diagnosed only on presence of K, Si, Al, and Fe (practically without Mg) in energy dispersive spectrum and according to the refraction index $n_m \approx 1.63$; it contains in its structure about 2 – 3 wt.% F (according to microprobe analysis with WDS). In some samples it is partly hydrated.

Table 1. **Chemical composition of micas of the Glubostrovskaya vein (wt.%)**

№ an.	SiO_2	Al_2O_3	FeO	MnO	K_2O	Na_2O	Rb_2O	Li_2O	F	H_2O	Total
1	44.70	30.52	5.17	1.28	9.40	0.46	1.02	0.97	2.40	3.90	99.82
2	45.50	21.80	4.27	5.85	9.60	0.25	1.67	3.98	7.70	–	100.64*
3	46.15	34.72	0.52	1.20	10.00	0.13	0.58	0.02	n.d.	5.65	98.97
4	n.d.	n.d.	0.27	0.17	10.70	0.46	0.40	<0.02	n.d.	n.d.	

Empirical formulas (muscovite is calculated on 7 cations, masutomilite – on 8 cations)

1 $(K_{0.89}Na_{0.07}Rb_{0.05})_{1.01}(Al_{1.30}Li_{0.29}Fe_{0.32}Mn_{0.08})_{1.99}(Si_{2.62}Al_{1.38})_4O_{10}(OH)_{1.02}F_{0.56}$;

2 $(K_{0.98}Rb_{0.09}Na_{0.04})_{1.11}(Li_{1.28}Al_{0.93}Mn_{0.40}Fe_{0.29})_{2.90}(Si_{2.87}Al_{1.13})_4O_{10}F_{1.97}$;

3 $(K_{0.96}Rb_{0.03}Na_{0.02})_{1.01}(Al_{1.85}Mn_{0.08}Fe_{0.03}Mg_{0.02}Ca_{0.01}Li_{0.01})_{2.00}(Si_{2.76}Al_{1.24})_4O_{10}(OH)_{1.51}$.

*Note. 1 – lithium-ferriferrous muscovite, 2 – ferroan masutomilite, 3 – manganous muscovite dark-violet (pseudomorphoses on topaz), 4 – pinkish muscovite ("foamy"). FeO content is calculated from Fe_2O_3; water is determined as a loss during calcination (minus fluorine). * – in analysis 2 it is also revealed 0.02 wt. % Cs_2O. n.d. – not determined, dash – element is not revealed. Analyst M.N. Maljaryonok – chemical analyses (analyses 1–3) and atomic absorption (rare alkalis and analysis 4).*

Table 2. **Results of calculation of X-ray patterns of lithium-ferriferrous muscovite (1), ferroan masutomilite (2), pseudomorphoses of muscovite (3) on topaz and late muscovite-"foamy" (4)**

1		2		3		4	
d, Å	*I*	*d*, Å	*I*	*d*, Å	*I*	*d*, Å	*I*
9.96	51	9.96	33	10.04	53	10.01	29
4.98	16	4.97	7	5.02	40	5.01	31
3.486	2	3.86	6	4.48	2	4.45	1
3.321	100	3.637	10	3.501	2	3.488	1
3.199	4	3.349	14	3.344	100	3.335	100
2.990	4	3.310	100	3.203	3	3.195	1
2.861	2	3.085	14	2.993	3	2.987	1
2.786	2	2.899	11	2.795	3	2.790	1
2.569	1	2.672	6	2.558	3	2.556	1
2.491	9	2.585	7	2.507	11	2.503	12
1.993	34	2.482	11	2.006	51	2.127	1
1.648	1	1.987	37	1.664	1	2.003	62
1.423	2	1.657	4	1.651	1	1.669	1
		1.516	2	1.524	1		

Note. X-ray diffractometer DRON-2.0, CuKα-radiation, 0.02°/min. Tests 1 and 2 – with vaseline. Analyst T.M. Rjabuhina.

According to the composition, pinkish-greenish-grey large-platy **muscovite** from the block zone of the vein is lithium-ferriferrous and containing F, with a considerable impurity of manganese that cause a pinkish shade of mica (Table 1, analysis 1); its X-ray diffraction pattern is closer to the polytype 1M (Table 2). Intergrowths of muscovite with quartz, albite, topaz and microcline are most often, but we also meet its intergrowths with masutomilite (without replacement features) and accessory minerals.

Masutomilite in this vein amazes us with size of plates (up to 15–20 cm) and depth of pinkish-violet shade of colour (Fig. 3). Unfortunately, long contact with water in summer and freezing in winter has led to quite often fractionizing of samples during their extraction. Masutomilite is ferroan, containing the following elements (wt.%): MnO 5.85, Li_2O 3.98 and Rb_2O 1.67 (Table 1, analysis 2), polytype 1M. According to the A.S. Talantsev's report (1959), this mineral ("lepidolite") contained 5.6 wt.% Li_2O (without indication of the method used and without the complete analysis).

Fine-grained dark-violet muscovite, forming partial or full pseudomorphoses on topaz (Fig. 4), is distinguished by small impurity of iron, lithium and rubidium (Table 1, analysis 3) with presence of 1.2 wt.% MnO (as in lithium-ferriferrous large-lamellar muscovite). Its X-ray pattern is closer to the polytype $2M_1$.

Aggregates of late pinkish and pinkish-yellowish mica-"foamy" from the central part of the vein are composed by muscovite (according to the X-ray diffraction pattern – illite $2M_1$), poor in Fe and Mn (Table 1, analysis 4). Its thin intersecting small veins sometimes occur in dark-violet muscovite pseudomorphoses on topaz.

Topaz forms two differing morphological types. Earlier bluish translucent and transparent grains of topaz are small (up to 2 cm), with rhomboid section of the habitus prism *m* {110}. They form aggregates with lithium-ferriferrous muscovite and greenish-yellowish beryl in the subzone of transition to the block pegmatite. In the block zone, in aggregates with masutomilite topaz occurs in crystals up to 10–20 cm in size, cloudy, greyish-or bluish-white in colour, with "square" section of habitus prism *l* {120}, advanced basal plane *c* {001} and small facets of a prism *y* {021}, visually determined on some heads of crystals replaced by muscovite (see Fig. 4b). Several clear isometrical pseudomorphoses on topaz are found in grey quartz of the quartz nucleus. The chemical composition of topazes was not determined, but according to the dimension d_{040} = 2.198 – 2.200 Å on their X-ray patterns, the content of fluorine in topazes is about 18.5 – 19 wt.% (Popova, Dolgopyat, 1989).

Different in colour **beryl** (Fig. 5), differs also in the composition of impurities. Pinkish beryl from the block zone contains more alkalis (Li and Rb – in 4 times, Cs almost in 10 times, Na and K – almost twice) in comparison with greenish-yellowish beryl from the association with lithium-ferriferrous muscovite (Table 3). A wide strip in the region of about 720 nm is precisely shown in the cathodoluminescence spectrum of pinkish alkaline beryl. X-ray patterns of differently coloured samples of beryl are practically identical.

Garnets in pegmatitee have different composition, colour and size and vary as follows: from rare and fine grains of pale-pink **Ca-containing almandine** in the endocontact zone of the vein and orange-red **manganous almandine** in the graphic zone up to rather large pinkish-orange and pale-orange spessartine (up to 1 – 1.5 cm in diameter) in the block zone of the pegmatite (Table 4.).

Manganocolumbite in the graphic zone of the pegmatite is fine-grained (up to 1 – 2 mm in size), short-columnar or tabular and lengthened along the axis [001] (Fig. 6a, b), and in the block zone it is tabular, flattened along the axis [100] and reaches up to 1 – 2 cm in size (Fig. 6c, d).

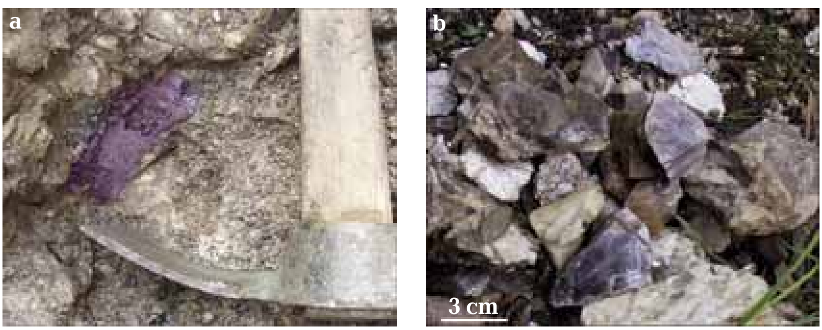


Fig. 3. Masutomilite (20 cm) in the mine wall (a) and its fragments in the dump (b).

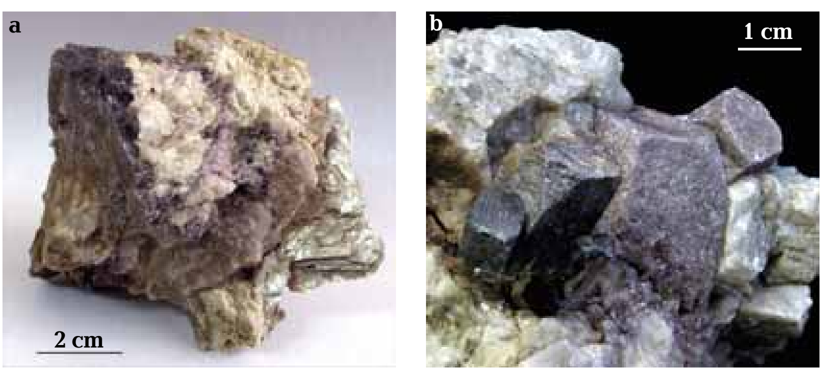


Fig. 4. Topaz (in the center), replaced from edges by dark-violet fine-grained muscovite (a), and complete pseudomorphoses of such muscovite on topaz with preservation of crystals form (b).

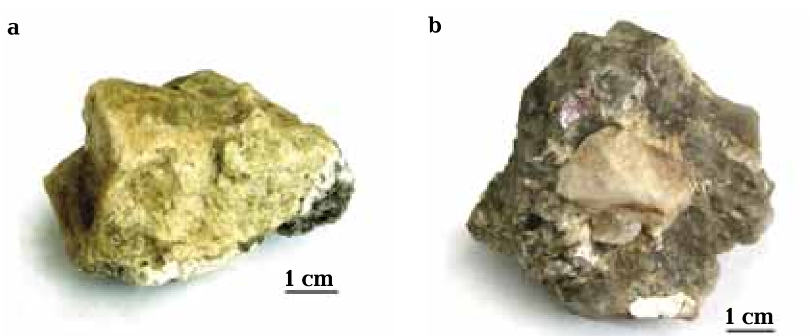


Fig. 5. Two types of beryl: early greenish-yellow (a) and later pinkish alkaline (b).

Table 3. **Contents of impurities in beryl different in colour**

Colour of beryl	ppm			wt.%	
	Li	Rb	Cs	Na	K
Yellowish	101.7	16.7	28.3	0.08	0.04
Pinkish	400.0	77.0	277.5	0.14	0.07

Note. Atomic-absorption method, analyst M.N. Maljaryonok.

Table 4. **Chemical composition of garnets from the pegmatite (microprobe, wt.%)**

	1	2	3	4
SiO_2	37.55	36.60	36.43	36.47
TiO_2	0.07	0.02	–	–
Al_2O_3	21.05	20.53	20.58	20.65
FeO	24.90	24.03	8.14	4.14
MnO	6.59	17.53	34.75	38.72
MgO	0.38	0.06	–	–
CaO	9.14	1.02	0.22	0.30
Total	99.68	99.79	100.12	100.28

Formulas (calculated on 8 cations)

1 $(Fe_{1.68}Ca_{0.79}Mn_{0.45}Mg_{0.05})_{2.97}Al_{2.00}(SiO_4)_3$; Ca-containing almandine

2 $(Fe_{1.66}Mn_{1.23}Ca_{0.09}Mg_{0.01})_{2.99}Al_{2.00}(SiO_4)_3$; Mn-containing almandine

3 $(Mn_{2.42}Fe_{0.56}Ca_{0.02})_{3.00}Al_{2.00}(SiO_4)_3$; Fe-containing spessartine

4 $(Mn_{2.69}Fe_{0.28}Ca_{0.03})_{3.00}Al_{2.00}(SiO_4)_3$; spessartine

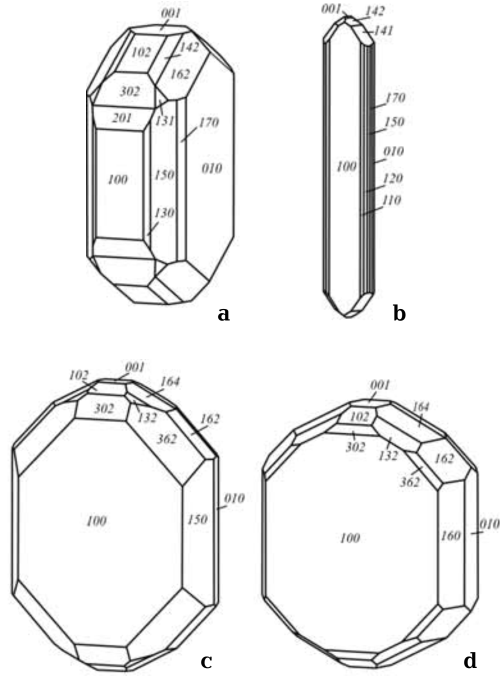


Fig. 6. Form of crystals of manganocolumbite from the graphic pegmatite (a, b) and block zone of the vein (c, d).

The composition of the early manganocolumbite from the graphic zone and the same mineral in internal parts of tabular grains from the block zone is characterized by increased contents of Nb_2O_5 (50–60 wt.%) and FeO (1.7–2.1 wt.%) and lower concentration of Ta_2O_5 (19–27 wt.%); later zones of manganocolumbite tabular crystals contain 37–48 wt.% Ta_2O_5 (Table 5; Fig. 7). A slight surplus of cations (Mn + Fe) is observed in the empirical formulas calculated according to the results of microprobe analyses that can be caused by presence of thin films composed by hydroxides of these elements on the thinnest cracks in manganocolumbite.

Fine grains of brown **cassiterite** (1–2 mm in diameter), inside which it is possible to distinguish darkly and light-coloured thin zones, are presented by subisometrical twins on {101} with habitus facets of the dipyramid *s* {111} (Fig. 8). Its most light, brownish-yellowish zones (containing 99.4 wt.% SnO_2) include insignificant impurities of MnO and Ta_2O_5 (0.07–0.12 wt.%). The composition of black-brown grain is as follows (wt.%): SnO_2 86.64; Ta_2O_5 10.64; Nb_2O_5 0.91; MnO 1.73; FeO 0.07; total 99.99 (average from two analyses). It corresponds to the empirical formula $(Sn_{0.88}Ta_{0.07}Mn_{0.04}Nb_{0.01})O_2$. In other similar grains the ratio Mn:Ta = 1:2, that gives the basis to assume the presence of about 4 mol.% of "manganotantalite" end member $MnTa_2O_6$ (or microinclusions of manganotantalite, yet not found) in cassiterite.

Crystals of **monazite-(Ce)** in the pegmatite are brownish-yellow, transparent up to translucent, up to 1–3 mm in size. They vary in shape, but they are rather simple in form (Fig. 9). Among the rare-metal elements, in the earlier crystals prevail Ce and Nd, and in the later monazite (from the block zone) prevail Ce and Sm; the latest monazite also contains more thorium at the relative uniformity of the composition (Table 6).

Fine-grained crystals of **microlite** (up to 1–1.5 mm in diameter) are very unusual in this vein: they are translucent grayish-yellow, greenish and brownish-greenish octahedrons with narrow and rare "strips" of rhombic-dodecahedron facets and even more rare tiny facets of the cube (according to their appearance, grains can be accepted for xenotime). Sometimes crystals are spotty in colour or obviously zonal, cloudy brownish, with a greenish translucent or transparent peripheral zone. Impurities of Sn, U and insignificant of Ba are

Table 5. ***Chemical composition of manganocolumbite crystal zones (microprobe, wt.%)***

	Fig. 7a			Fig. 7b			
	1	2	3	4	5	6	7
MnO	17.60	17.23	17.32	18.93	17.70	18.16	17.34
FeO	1.68	0.35	0.32	0.18	–	–	2.07
Nb_2O_5	54.45	33.40	33.14	52.23	39.82	44.50	60.89
Ta_2O_5	25.50	48.34	48.56	27.44	41.35	37.48	18.80
TiO_2	0.70	0.65	0.64	0.55	0.65	0.11	0.54
SnO_2	–	–	–	0.28	0.11	0.03	–
Total	99.93	99.97	99.98	99.61	99.63	100.28	99.64

Formulas (O=6)

1	$(Mn_{0.93}Fe_{0.09})_{1.02}(Nb_{1.53}Ta_{0.43}Ti_{0.03})_{1.99}O_6$;
2	$(Mn_{1.01}Fe_{0.02})_{1.03}(Nb_{1.05}Ta_{0.91}Ti_{0.03})_{1.99}O_6$;
3	$(Mn_{1.02}Fe_{0.02})_{1.04}(Nb_{1.04}Ta_{0.92}Ti_{0.03})_{1.99}O_6$;
4	$(Mn_{1.01}Fe_{0.01})_{1.02}(Nb_{1.49}Ta_{0.47}Ti_{0.03}Sn_{0.01})_{2.00}O_6$;
5	$Mn_{1.01}(Nb_{1.21}Ta_{0.76}Ti_{0.03})_{2.00}O_6$;
6	$Mn_{1.01}(Nb_{1.32}Ta_{0.67}Ti_{0.01})_{2.00}O_6$;
7	$(Mn_{0.89}Fe_{0.11})_{1.00}(Nb_{1.67}Ta_{0.31}Ti_{0.02})_{2.00}O_6$

Note. Analyses 1–3 and 4–6 – consecutive zones of two crystals from the center to the edge (from the block zone of the vein); analysis 7 – earlier manganocolumbite from the graphic zone of the pegmatite.

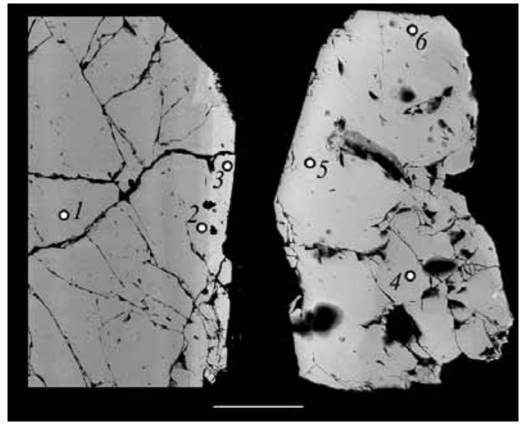
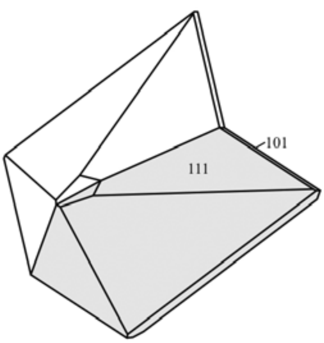


Fig. 7. Parts of zonal crystals of manganocolumbite. BSE (figures near points – numbers of analyses in Table 5).



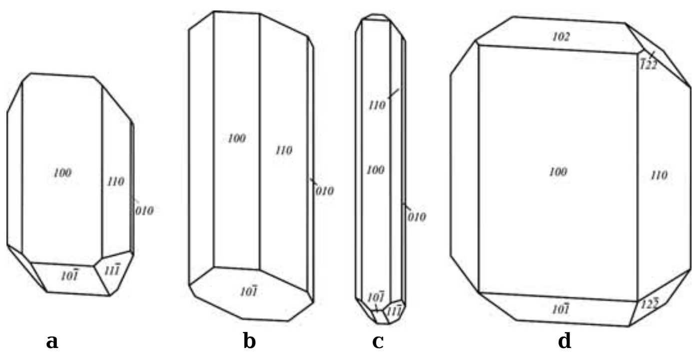


Fig. 8. Twin of cassiterite along {101}.
Fig. 9. Form of monazite-(Ce) crystals in consecutive zones the pegmatite (from early to late).

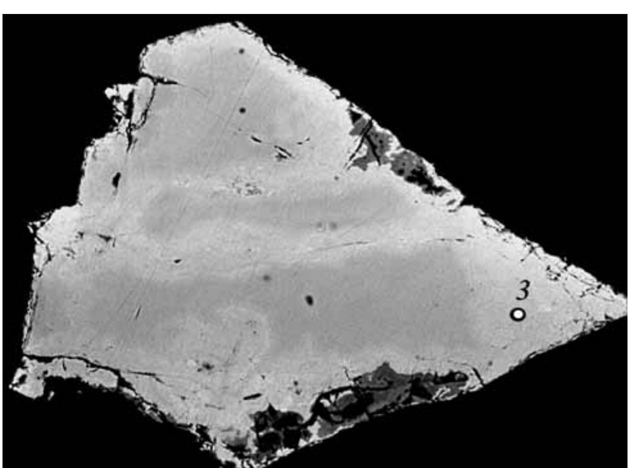


Fig. 10. Grain of microlite (light grey) with more light sites of its replacement by parabariomicrolite. BSE (point 3 – see Table 7).

Table 6. **Chemical composition of monazite-(Ce) (microprobe, wt.%)**

	1	2	3	4
CaO	1.35	2.36	2.37	2.71
La_2O_3	5.41	4.80	4.68	4.18
Ce_2O_3	21.72	17.75	15.98	15.89
Pr_2O_3	5.29	2.44	2.46	2.98
Nd_2O_3	15.52	9.71	9.94	9.84
Sm_2O_3	5.13	14.13	13.58	13.79
Gd_2O_3	8.38	9.78	9.72	9.41
Tb_2O_3	–	0.19	0.18	0.61
ThO_2	5.57	7.85	8.20	8.38
UO_2	1.09	0.47	0.66	1.23
P_2O_5	27.87	29.05	29.08	29.15
SiO_2	1.27	1.00	1.10	0.82
Total	98.60	99.53	99.55	98.99

Formulas (O = 4)

1 $(Ce_{0.32}Nd_{0.22}Gd_{0.11}La_{0.08}Pr_{0.09}Sm_{0.07}Ca_{0.06}Th_{0.05}U_{0.01})_{1.0}(P_{0.95}Si_{0.05})_{1.00}O_4$;

2 $(Ce_{0.26}Sm_{0.19}Nd_{0.14}Gd_{0.13}La_{0.07}Pr_{0.04}Ca_{0.10}Th_{0.07})_{1.00}(P_{0.97}Si_{0.04})_{1.01}O_4$;

3 $(Ce_{0.25}Sm_{0.19}Nd_{0.14}Gd_{0.13}La_{0.07}Pr_{0.04}Ca_{0.10}Th_{0.07}U_{0.01})_{1.00}(P_{0.97}Si_{0.04})_{1.01}O_4$;

4 $(Ce_{0.23}Sm_{0.19}Nd_{0.14}Gd_{0.12}La_{0.06}Pr_{0.04}Ca_{0.10}Th_{0.08}U_{0.01})_{0.97}(P_{0.89}Si_{0.03})_{1.01}O_4$.

Note. Analyses 2–4 – in one crystal from the center to the edge.

Table 7. **Chemical composition of microlite (1–2) and parabariomicrolite (3) from the Glubostrovskaya vein (microprobe, wt.%)**

	1	2	3
Na_2O	4.50	5.30	–
CaO	9.95	10.15	0.69
MnO	–	–	0.16
BaO	0.34	0.20	10.10
SnO_2	1.74	2.12	2.74
UO_2	4.95	0.42	4.98
Nb_2O_5	4.50	5.52	5.49
Ta_2O_5	70.60	72.70	73.60
F	3.35	3.50	–
Total	99.93	99.91	97.76

Formulas (analyses 1 – 2 are calculated on 4 cations, analysis 3 – on 5 cations)

1 $(Na_{0.82}Ca_{1.00}U_{0.10}Sn_{0.07}Ba_{0.01})_{2.00}(Ta_{1.80}Nb_{0.19})_{1.99}O_6F_{1.00}$;

2 $(Na_{0.93}Ca_{0.98}Sn_{0.08}U_{0.01}Ba_{0.01})_{2.01}(Ta_{1.78}Nb_{0.22})_2O_6F_{0.99}$;

3 $(Ba_{0.67}U_{0.19}Ca_{0.13}Mn_{0.02})_{1.01}(Ta_{3.39}Nb_{0.42}Sn_{0.18})_{3.99}O_{10}(OH)_2$.

Note. Dash – element is not revealed. Conditions of microprobe analysis (as well as in the previous tables) are specified in the text; fluorine is determined with the help of WDS on JXA-733 in the Institute of Mineralogy, UB RAS, (Miass), analyst V.A. Muftakhov.

determined in different grains (Table 7, analyses 1 – 2). In some grains (from the periphery and near cracks), the microlite is replaced by uraniferrous **parabariomicrolite** (Fig. 10). This mineral was not observed earlier in the Urals. The process of replacement obviously occurred with removal of Na, Ca, and F and influx of Ba (Table 7, analysis 3). Rare brownish-white crystals and split joints of **zircon** (cyrtolite) 1 – 3 mm in size are characterized by a high concentration of HfO_2 (10 – 13 wt.%) and a small impurity of thorium and uranium (0.1 – 0.4 wt.%).

Discussion of results and conclusions

Glubostrovskaya vein of granite pegmatites is closest to the known in Urals veins of the Svetlinskoye pegmatite field (Talantsev, 1988) and Murzinka (Popova *et al.*, 2002) with beryl, topaz, microlite, cassiterite, monazite, ferrocolumbite, manganocolumbite, manganotantalite and lithium-bearing micas – muscovite and lepidolite. But the Glubostrovskaya vein is distinguished by the presence of large plates of ferroan masutomilite reaching up to 5 – 20 cm in size. In pegmatites of the Urals, less-ferriferrous pinkish-violet masutomilite reaching up to 2 cm in size and containing 6.6 – 7.7 wt.% MnO overgrown on muscovite was found in the Ilmeny mountains (Belogub, 1992). In the Mokrusha vein of the Alabashka field, free of Fe brownish-violet masutomilite with 5 wt.% MnO is observed in crystals of lithium micas as internal zones (up to 1 cm in thickness) alternating with trilithionite (zinnwaldite) and replaced be polylithionite to the periphery (Popova *et al.*, 2002). Masutomilite with 8 wt.% MnO that forms an internal zone in a 10-cm plate of mica with an external zinnwaldite (trilithionite) zone was firstly time discovered in Japan (in a small cavity in granite pegmatite of the Tanakamiyama deposit) in 1975. Ferroan masutomilite with 4.27 wt.% MnO was also found in the same place, in the Tavara deposit (Minerals, 1992). Masutomilite is known from pegmatites of Algeria, Czech Republic, USA (http://www.mindat.org/min-2588.html). Ferroan masutomilite from the Glubostrovskoye occurrence of lithium in the Southern Urals differs from the Japanese one not only by its size, but also by higher concentrations of iron and manganese and lower concentration of lithium. Late pinkish beryl is enriched with rare alkalis, monazite-(Ce) is enriched in samarium, and zircon is enriched in hafnium.

Parabariomicrolite of the Glubostrovskaya vein as well as Brazilian parabariomicrolite from the granite pegmatite Alto du Giz in Brazil (Ercit *et al.*, 1986; cited according to: Kudryashov, Rozhdestvenskaya, 1988) metasomatically overgrows on microlite, but differs from the

Brazilian one by its yellowish-greenish colour and contains essential impurities of U, Ca, Nb, Sn (see Table 7, analysis 3). As far as it is known, the parabariomicrolite discovery is the first in the Urals and in Russia (and the second in the world).

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