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СТРУКТУРНО-ХИМИЧЕСКИЕ ОСОБЕННОСТИ КАЛИЕВЫХ ПОЛЕВЫХ ШПАТОВ ИЗ ПЕГМАТИТОВ ЛИПОВКИ (СРЕДНИЙ УРАЛ)

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Structural and chemical features of potash feldspars from pegmatites of the Lipovskoe vein field (Middle Urals)

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The authors studied structural and chemical properties of the potassium feldspars from different types of granitic pegmatites of Lipovskiy vein field, located 70 km northeast of Ekaterinburg city, in vicinity of the Lipovskoe village. These pegmatites gained worldwide fame at the beginning of the last century because of the active extraction of pink tourmalines (rubellites). For the study authors selected potassium feldspars from two types of granitic pegmatites – conventional and contaminated (desensitized granite veins were untested, as potassium feldspars are absent in them). According to the powder roentgenometry, orthoclase and intermediate microcline were only in normal granitic pegmatites, and intermediate and maximum microcline – in lithium-bearing contaminated veins. Microprobe analysis of the potassium feldspars also showed variability in their chemical composition from the structural ordering of minerals. Microclines and orthoclases from the ordinary pegmatites are enriched by sodium and depleted by cesium and rubidium, and potassium feldspars from the lithium-bearing veins, on the contrary, are depleted by sodium and enriched by rare alkaline elements. Authors established that at increase of the contents of Rb and Cs there is an increase of the degree of triclinity of the potassium feldspars, i.e. in substantially pure (maximum) microcline forms in the contaminated pegmatites of Lipovskiy vein field. An interesting fact is the drastic decrease in the number of perthite intergrowths of albite in a matrix of potassium feldspar from the contaminated pegmatites compared to conventional granite veins. In many samples of microcline from the contaminated pegmatites, perthite intergrowths are visually absent and, apparently, make up microperthite intergrowths.

Keywords: potassium feldspar; granitic pegmatites; Lipovskoe vein field; Middle Urals.

Изучены структурно-химические особенности калиевых полевых шпатов из разных типов гранитных пегматитов Липовского жильного поля, расположенного в 70 км северо-восточнее города Екатеринбурга и в окрестностях села Липовское. Данные пегматиты приобрели всемирную известность в начале прошлого века в результате активной добычи розовых турмалинов (рубеллитов). Для исследования отбирались калишпаты из двух типов гранитных пегматитов – обычных и контаминированных (десилицированные гранитные жилы не опробовались, так как в них калиевые полевые шпаты отсутствуют). По данным порошковой рентгенометрии установлено, что ортоклаз и промежуточный микроклин отмечаются только в обычных гранитных пегматитах, а промежуточный и максимальный микроклины – в литиеносных контаминированных жилах. Микрозондовый анализ калиевых полевых шпатов также показал изменчивость их химического состава от структурной упорядоченности минералов. Микроклины и ортоклазы из обычных пегматитов обогащены натрием и обеднены цезием с рубидием, а калиевые полевые шпаты из литиеносных жил, наоборот, обеднены натрием и обогащены редкими щелочными элементами. Установлено, что при нарастании содержаний Rb и Cs происходит увеличение степени триклинности калиевых полевых шпатов, т. е. в контаминированных пегматитах Липовского жильного поля формируется практически чистый (максимальный) микроклин. Интересным фактом является резкое снижение количества пертитовых вростков альбита в матрице калиевого полевого шпата из контаминированных пегматитов по сравнению с обычными гранитными жилами. Во многих образцах микроклина из контаминированных пегматитов пертитовые вростки визуально отсутствуют и, по всей видимости, слагают микропертитовые вростки.

Ключевые слова: калиевый полевой шпат; гранитные пегматиты; Липовское жильное поле; Средний Урал.

Granite pegmatite of the Lipovskoe vein field occurs on the eastern slope of the Middle Urals (70 km to the northeast of Ekaterinburg and 5 km to the west of the village of Lipovskoe). Pegmatite hosts the world famous and already finished Lipovskoe deposit of pink tourmaline (rubellite). Pegmatite occurs in the syncline structure located between three large granite massifs, namely Murzinskii (from the northwest), Aduiskii (from the southwest), and Sokolovskii (from the east) (Fig. 1). This syncline is composed of metamorphic rocks related to the Murzinskaya Formation (presumably of Proterozoic age) with the prevalence of various gneisses, schists and amphibolites [1, 2 and others]. This formation contains individual bodies of serpentinite and marble, which are usually tectonically alternating. With karst marbles and weathering crusts of serpentinites are connected to well-known and already spent deposit of silicate-nickel ores. Granite pegmatite are widely distributed within of the Lipovskoe vein field and are presented by three types of rare-metals – normal (chrysoberyl-beryl), desiliconized (plagioclasite) and contaminated (lithium bearing).

Despite the widespread of pegmatites in the area and their relatively good mineralogical knowledge [2, etc.; along with our numerous data] we proved that potassium feldspar as the main rock-forming mineral of normal and contaminated pegmatites, remains virtually unexplored.

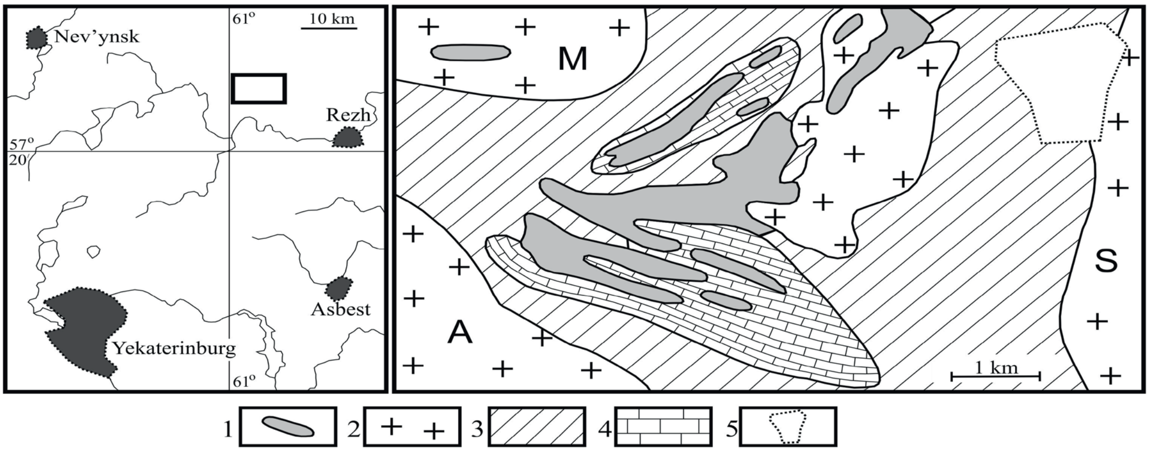

Figure 1. Geological scheme of the Lipovskoe vein field (modified after [1]). 1 – serpentinite; 2 – granite (A, Aduiskii massif; M, Murzinskii massif; S, Sokolovskii massif); 3 – gneiss and amphibolites; 4 – marble; 5 – contours of the Lipovskoe Village.

Various authors [2–4] mention microcline and orthoclase in granites and pegmatites of Lipovka, but without any diagnostic properties. The Lipovskoe vein field contains non-cavernous pegmatites with chrysoberyl in which orthoclase and miarolitic pegmatites are the rock-forming potassium feldspars, including the ones with a lithium mineralization, which, on the contrary, contain microcline [2]. We found it interesting to conduct a study of the structural and chemical characteristics of potash feldspars in the normal and contaminated pegmatites of the Lipovskoe vein field (desiliconized pegmatite were not included in research, since they contain only plagioclases).

For X-ray analysis we selected 14 samples of potassium feldspars from normal and from contaminated pegmatites (see Table 1). We collected all samples from the large-sized samples of quartz-feldspar graphics and block area, excluding sampling from miarols and cavities.

Table 1. List of studied potassium feldspars samples indicating the sampling locations.

№	Number of sample	Minerals	Sample connection
1	2л/09	Orthoclase	Plain granite pegmatite, quarry number 6. Dumortierite vein. Major «graphics». Coordinates: N 57°26'30,5''; E 61°06'02,5''
2	18-1л/13	Microcline intermediate	Normal granite pegmatite, quarry number 6. Dumortierite vein. Small «graphics». Coordinates: N 57°26'30,5''; E 61°06'02,5''
3	18-2л/13	Microcline intermediate	Normal granite pegmatite, quarry number 6. Dumortierite vein. Block area. Coordinates: N 57°26'30,5''; E 61°06'02,5''
4	34-4ла/11	Orthoclase	Normal granite pegmatite, quarry number 6. Chrysoberyl vein. Major «graphics». Coordinates: N 57°26'32,6''; E 61°06'08,6''
5	61л/11	Orthoclase	Normal granite pegmatite, quarry number 7. Nameless vein. Small «graphics». Coordinates: N 57° 26'52,2''; E 61°06'50,9''
6	35л/11	Microcline intermediate	Normal granite pegmatite, quarry number 6. Nameless vein. Major «graphics». Coordinates: N 57°26'29,6''; E 61°05'57,9''
7	95л/11	Orthoclase	Normal granite pegmatite, quarry number 4-5. Nameless vein. Major «graphics». Coordinates: N 57°25'49,5''; E 61°05'44,6''
8	23-5л/11	Orthoclase	Normal granite pegmatite, quarry number 6. German vein. Major «graphics». Coordinates: N 57°26'29,1''; E 61°05'41,0''
9	58л/10	Microcline intermediate	Contaminated pegmatite, quarry number 6. Khitnichya vein. Block area. Coordinates: N 57°26'30,8''; E 61°06'00,1''
10	27л/13	Microcline maximum	Contaminated pegmatite, quarry number 6. Khitnichya vein. Block area. Coordinates: N 57°26'30,8''; E 61°06'00,1''
11	47-20л/11	Microcline intermediate	Contaminated pegmatite, quarry number 6. Khitnichya vein. Major «graphics». Coordinates: N 57°26'30,8''; E 61°06'00,1''
12	8-1л/12	Microcline maximum	Contaminated pegmatite, quarry number 6. Khitnichya vein. Block area. Coordinates: N 57°26'30,8''; E 61°06'00,1''
13	1л/15	Microcline intermediate	Contaminated pegmatite, quarry number 6. Collapsed Kuryatnik vein. Block area. Coordinates: N 57°26'30,1''; E 61°05'47,7''
14	7-2л/12	Microcline intermediate	Contaminated pegmatite, quarry number 6. Sibiryachka vein. Lepidolite quicklime. Coordinates: N 57°26'29,1''; E 61°05'41,0''

Color of potassium feldspar from normal pegmatites is usually white, often with yellowish, grayish or pinkish shades. All studied potassium feldspars of this pegmatite type contained perthite intergrowths of albite. Potassium feldspar in the lithium-bearing pegmatites is more colorful and usually has a yellowish or greenish-light-gray color. Samples of potassium feldspars in the lithium-bearing veins typically contain perthite intergrowths of albite, but one can often visually observe the following pattern: in the large crystals from the block areas size of perthite intergrowths decreases (up to their complete disappearance) as it approaches the central part of the pegmatite, i.e. to the lepidolite zone.

We performed of X-ray analysis of potassium feldspars using diffractometer XRD-7000 (Shimadzu) in the IGG UB RAS (analyst O. L. Galakhova); we used Cu-emission, operation mode of X-ray tube: voltage – 40 kV, current – 30 mA. In the studied potassium feldspars we determined the triclinic degree, by the known formula $\Delta\rho = 12,5 \times (d_{131} - d_{1-31})$, which for the monoclinic feldspars is equal to zero, and for the most ordered microclines is equal to one. The evaluation of the structural condition of potassium feldspars is usually given by the content of aluminum in different T-positions. For pure potassium feldspars, one can make aluminum filling of these positions according to the formulas given in the well-known works [5 and others]. We can take values calculated using these formulas as the starting for clarification with the other structural parameters by the Rietveld method. We determined the degree of structural order of potassium feldspars using standard methods [6–8].

One can see the obtained results of X-ray analysis of potassium feldspar samples in Table 2. By analyzing the data, we can confidently say that the orthoclase appears only in the normal granitic pegmatites, and pure (maximum) microcline – in lithium-bearing contaminated veins. The intermediate microcline occurs in both types of pegmatites. For example, in the normal granitic pegmatite (dumortierite vein, quarry number 6) intermediate microcline composes fine quartz-feldspar graphics and blocky area, and a large quartz-feldspar graphic is already composed of orthoclase. In turn, for lithium-bearing veins we note interleaving of intermediate and maximum microcline. In general, the there is a tendency of growth of the degree of triclinic potassium feldspars from normal pegmatites to lithium-bearing veins. An interesting fact is that the drastic decrease in the number of perthite intergrowths of albite in the potassium feldspar matrix from contaminated pegmatites compared to usual granite veins. In many samples of potassium feldspar from contaminated pegmatites, perthite intergrowths are visually absent and, apparently, compose microperthite intergrowths.

In terms of triclinic of potassium feldspar, we can partly determine its conditions of formation in granitic pegmatites. As we previously noted, in the later stages of magmatic process and in the post-magmatic conditions orthoclase turns into microcline or is metasomatically replaced by it [9]. Favorable for the formation of microcline is a slowed process of mineral growth at low temperatures and an abundance of volatile components [7, 10]. There is an assumption that the structural state of potassium feldspar may affect the acidity of the mineral medium [11].

In triclinic terms of potassium feldspar, we can draw some conclusions about the potential productivity of the granite pegmatite. Regardless of their age and formation belonging, orthoclases are the most characteristic for unproductive and poorly productive on the crystal raw materials pegmatites. In the primary areas of productive pegmatites along with orthoclase, minimally triclinic and intermediate on the degree of triclinic potassium feldspars are the most common. Upon approaching the miarols and near-miarolitic areas, proportion of maximum microclines increases. In the miarols, crystals of potassium feldspars are typically less ordered, there often are orthoclases and minimally triclinic potassium feldspars, although some cases have maximum and intermediate microclines. Significant changes in fluid pressure, temperature and composition of the mineral medium contributed to formation in miarols of different in structural state potassium feldspars [12]. That is why we did not study the potassium feldspars from miarols of Lipovka granitic pegmatites.

The chemical composition of potassium feldspars is given in Table 3. There is a definite connection between the composition of potassium feldspars and their structural ordering. One can see that orthoclases contain larger sodium admixture than microclines and radiometric studies confirm this tendency. In general, the amount of minal albite in potassium feldspars from normal pegmatites varies within the range of 5–11%, and in potassium feldspars from contaminated veins albite content does not extend 3–5%. In addition, potassium feldspars from normal pegmatites contain virtually no admixtures of rubidium and cesium, and in microclines of contaminated pegmatites these impurities grow rapidly (total to 1–1.5 wt.% and can be considered as

Table 2. The results of X-ray analysis of potassium feldspar samples from pegmatites of Lipovka.

Number of sample	Potassium feldspar	Albite	Triclinic degree Δp (±0,003)	t_1o (±0,01)	t_2o	t_1m	t_2m
			Normal				
2л/09	69%	31%	0,293	0,599	0,053	0,295	0,053
18-1л/13	83%	17%	0,499	–	–	–	–
18-2л/13	48%	52%	–	–	–	–	–
34-4ла/11	64%	36%	0,269	0,579	0,060	0,302	0,060
61л/11	59%	41%	0,229	0,541	0,079	0,301	0,079
35л/11	81%	19%	–	–	–	–	–
95л/11	82%	18%	0,328	0,584	0,087	0,242	0,087
23-5л/11	67%	33%	0,269	0,569	0,070	0,291	0,070
			Contaminated				
58л/10	65%	35%	0,368	–	–	–	–
27л/13	68%	32%	0,898	0,949	0,014	0,023	0,014
47-20л/11	79%	21%	0,443	–	–	–	–
8-1л/12	75%	25%	0,875	–	–	–	–
1л/15	82%	18%	0,488	0,694	0,058	0,190	0,058
7-2л/12	89%	11%	0,658	0,797	0,039	0,125	0,039

Table 3. The chemical composition (wt.%) of potassium feldspars in pegmatites of Lipovka.

Pegmatites	Normal			Contaminated			
№	1	2	3	4	5	6	7
SiO_2	65,21	64,76	64,47	65,27	65,87	64,36	64,88
TiO_2	0,02	–	0,05	0,01	–	–	0,01
Al_2O_3	18,11	17,94	17,88	18,79	18,57	18,29	18,01
Cr_2O_3	0,06	0,14	0,01	–	–	0,02	0,03
FeO	0,02	0,03	0,01	–	0,01	–	–
MnO	–	–	0,01	–	0,03	0,01	0,02
MgO	0,01	–	0,01	–	0,01	–	–
CaO	–	–	–	–	–	–	–
Na_2O	1,21	1,05	0,58	0,32	0,47	0,28	0,52
K_2O	14,59	14,88	15,46	15,79	15,41	15,83	15,45
Rb_2O	0,04	0,02	0,09	0,23	0,22	0,61	0,55
Cs_2O	0,04	–	–	0,11	0,10	0,08	0,16
F	0,15	–	0,15	0,06	0,07	–	0,06
Total	99,46	98,82	98,73	100,57	100,76	99,48	99,69
Alb	11	10	5	3	4	3	5

Note: the analyzes were carried out on microanalyzer CAMECA SX 100 in IGG UB RAS, analyst V. V. Khiller. Analyses 1–3 – normal granitic pegmatites (Analyses 1–2 – orthoclase, Dumortierite vein; Analysis 3 – intermediate microcline, Dumortierite vein), Analyses 4–7 – contaminated pegmatites (4–5 Analyses – intermediate microcline, Khitnichya vein; Analyses 6–7 – maximum microcline, lepidolite quicklime from Sibiryachka vein); Alb – Minal of albite.

rubidium, cesium containing microclines), moreover, in association with lepidolite and colored tourmalines.

Many researchers believe that the impurities of rubidium, cesium, barium and have a direct impact on the ordering of potassium feldspars structure. However, unfortunately, various scientists obtain conflicting results. For example, some argue that upon considerable enrichment of rubidium and cesium of potassium feldspar there appears a direct dependence of the growth of the monoclinic phase [13], i. e., feldspar passes into orthoclase. At the same time, according to V. E. Zagorskiy [11] in miarolitic pegmatites of Malkhan deposit, just the opposite takes place in potassium feldspars, with an increase in content of rubidium and cesium occurs an increase in on the triclinic degree of potassium feldspar, i.e. microcline forms. Our results for the potassium feldspars from Lipovka pegmatites are fully consistent with V. E. Zagorskiy data.

Thus, we studied the structural and chemical properties of potassium feldspars from different types of granitic pegmatites of the Lipovskoe vein field. According powder roentgenometry, we established that orthoclase and intermediate microcline are only in the normal granitic pegmatites, and the intermediate and maximum microclines are in lithium-bearing contaminated veins. Microprobe analysis of potassium feldspars also revealed variability of the chemical composition of the structural ordering of minerals. For example, potassium feldspars from normal pegmatites are enriched with sodium and are depleted with cesium and rubidium, and potassium feldspars from lithium-bearing veins – vice versa.

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