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Polychromic tourmalines from rare-metal granite pegmatites of the Medvedevsky rare metal deposit (Middle Urals)

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The relevance of the work is the specification of the genesis of the Medvedevsky rare-metal tourmaline deposit. To this end, as part of the work, a comparison was made of the chemical composition and trace amounts of tourmaline with the known tourmalines of the Lipovsky deposit.
The aim of the work is to study the features of the structure and compare the chemical and trace element composition of tourmalines of the Medvedevsky deposit with tourmalines of the Lipovsky field.
Research methodology. To study the chemical composition of tourmaline from the Medvedevsky deposit, a Jeol JSM-639LV scanning electron microscope with the EDS X-max 80 attachment was used. The trace element composition was studied by the ICP–MS method using the ELAN 9000 instrument. The original description was carried out using the MBS-10 binocular microscope and the Carl Zeiss petrographic microscope.
Results The data on the structural features, chemical and trace element composition of polychromic tourmaline from the Medvedevsky rare metal deposit are given.
Conclusion. A mineralogical study was conducted and the chemical and trace element composition of polychromic tourmaline from the Medvedevsky rare metal deposit was studied. A comparison is made with the chemical composition of tourmalines from the Lipovsky deposit.

Keywords: the Urals, chemical composition of tourmaline, Medvedevsky rare metal deposit, pegmatites, Ural emerald mines.

Introduction

Russian precious and semiprecious stones are a global brand; they are associated with the word “Ural”. Everyone knows that the Urals are rich in precious and semiprecious stones. However, at the moment, most of the deposits being developed in the XIX – XX centuries are flooded and there is no work with them. Occurrences of colored tourmaline are very rare, and any new occurrence is interesting to study [1]. The Medvedevsky rare metal deposit was discovered in the 1960s and was studied in detail by the Makhnevskaya exploration crew. Its area is about 5 km^2. It is located 30 km north-east of the Nizhnyaya Salda (Middle Urals) [2]. The deposit is out of use now; it is a series of grass-covered main drains and dug holes.

Geology aspects of the Medvedevsky rare metal deposit

The Medvedevsky rare metal deposit is localized in the body of the Talitsky ultrabasic massif represented by massive apoperidotite serpentinites. The observed thickness of serpentinites is about 1.5 km. The massif is elongated in the submeridional direction; it embeds in the interstratified metamorphic stratum composed of amphibole, quartz-sericitic, quartz-chlorite, chlorite-epidote, and less commonly albite schists. The metamorphic complex borders in the east on the medium-grained biotite granites of the Gaevsky massif, which is the northern extension of the Murzinsky massif [2]. In the northern part, serpentinites are bordered by albitized pegmatoid granites lying subparallel to the boundaries of the massif (Fig. 1). Metasomatic zones are observed in serpentinites; they are represented by intensive phlogopite mica. This process is especially intense around the feldspath lenses, which, as a rule, have a northeast strike. The thickness of the lenses varies widely, reaching several tens of meters in the northern part of the Talitsky massif. The lenses contain, in addition to feldspar, mica and beryl of a dark green and greenish-yellow color. The content of beryl can reach 15% of the volume of the rock [3].

Pegmatites in the deposit are represented by poorly differentiated microcline-albite and albite veins. The mineralogical and structural features of pegmatite bodies are explained by different crystallization conditions and remoteness from the parent vent. Pegmatites of the internal zones of the Gaevsky massif are close to normal in composition and structure. Pegmatites localized to exocontact, including those in serpentinites of the Talitsky massif differ from the pegmatites of the internal zones by a high content of rare-metal and rare-earth elements (niobium, tantalum, beryllium, ytterbium, lithium, etc.). The main rock-forming minerals of all types of pegmatites are microcline, oligoclase, albite, quartz, and muscovite. The bodies have a medium and coarse-grained structure, sometimes having a block-system. The endocontact parts of the veins are composed of the albite-oligoclase zone with a low thickness, intensely sericitized and often kaolinized. Frequently, the albite-oligoclase zone is completely replaced by the muscovite-quartz-albite complex. Pegmatite veins can be traced up to 600 m on the strike having mostly near east-west strike. The thickness of veins varies from 0.5 to 12 m, decreasing for feathering-out to 0.1–0.3 m [4].

To compare the chemical composition of tourmaline of the Medvedevsky deposit, the results of the chemical composition of the tourmaline from the well-known Ural polychrome tourmaline deposit were used, that is Lipovsky field, which is located in the Middle Urals, in the Rezh district of the Sverdlovsk region. It is located 35 km south-southeast of the Medvedevsky deposit. Pegmatites of the Lipovsky field are confined to a synclinal structure sandwiched between three large granite massifs – Murzinsky (from the northwest), Aduysky (from the southwest) and Sokolovsky (from the east). The syncline itself is composed of metamorphic rocks belonging to the Murzinskaya suite (presumably Proterozoic), gneisses of different composition and amphibolites [5].

Field works and primitive description

During the field works in 2016, a pegmatite vein with a thickness of 2 m was studied, from which several samples were taken (Fig. 2). The vein is located in quartz-chlorite schists and is composed of microcline-albite-muscovite-quartz aggregate. The gar-

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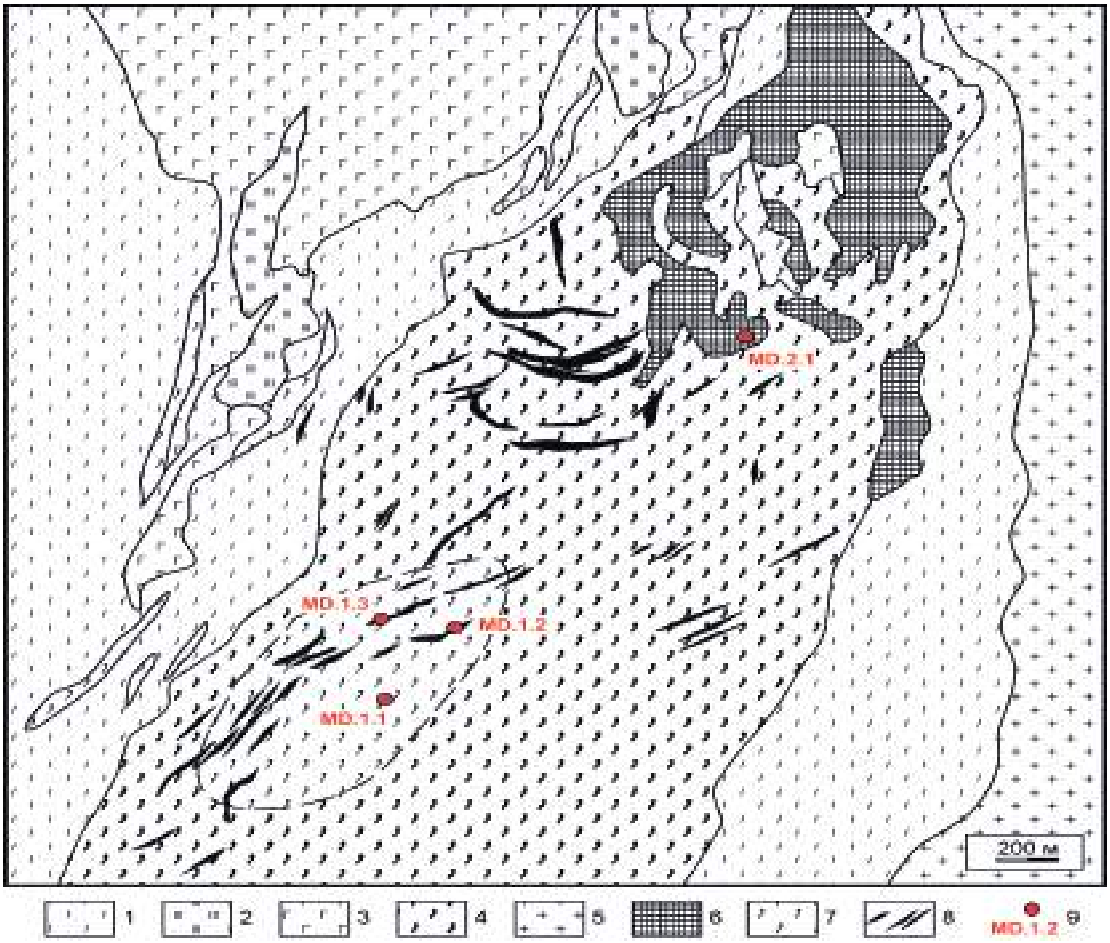

Figure 1. Geology aspects of the Medvedevsky occurrence (based on materials of the Makhnevskaya geological exploration crew of the Zauralsk expedition, 1964). 1 – amphibole schists; 2 – silica clay; 3 – amphibolized gabbro; 4 – serpentinites; 5 – biotite granites; 6 – pegmatoid granites; 7 – glimmerites; 8 – beryl-plagioclase lenses; 9 – sampling points.

Рисунок 1. Схема геологического строения проявления Медведевское (по материалам Махневской геологоразведочной партии Зауральской экспедиции, 1964 г.). 1 – амфиболовые сланцы; 2 – опоки; 3 – амфиболизированное габбро; 4 – серпентиниты; 5 – биотитовые граниты; 6 – пегматоидные граниты; 7 – слюдиты; 8 – берилл-плагиоклазовые линзы; 9 – точки отбора проб.

net crystals ranging from 0.1 to 2 mm in feldspar and light mica, presumably lepidolite, are noted in the vein in the form of large scales ranging in size from 0.5 to 2.5 cm.

When studying samples of microcline-plagioclase pegmatite, we have found two types of tourmaline crystals. *The first type* is found inside the plagioclase. It is represented by fissured prismatic crystals from 1 to 5 mm along the long axis and rarely radiated aggregates up to 4–5 mm. Color is black; sometimes brown in thin shears. *The second type* is found in small vugs and "blowing holes" of plagioclase and is represented by crystals up to 5 mm along the long axis and 2 mm in cross-section. The color varies from dark brown to light pink. In crystals, transverse zonation is often observed: the center is brownish-violet, the edges are grayish-pink (Fig. 3).

Methods of studying the characteristics of the composition of polychrome tourmaline

To study zonation of tourmaline, polished thin sections were made with the orientation of thin rock section along with the elongation of the crystal. When studying the zoned tourmaline of the second generation in thin sections, multiple cracks and deformation disturbances inside the crystals were found. In many places (outside the crystals and inside near the cracks), tourmaline is replaced by muscovite; that indicates overlapped secondary changes after the crystallization of the mineral (Fig. 4, 5). Relations (contacts) with plagioclase and microcline are uneven.

Methods of studying the chemical and trace element composition of tourmaline

To study the chemical composition of the previously obtained polished thin sections were used. The composition of the zoned tourmaline (mainly transverse zonation) was studied using the Jeol JSM-639LV scanning electron microscope with the EDS X-max 80 attachment (operator is I. A. Gottman, Zavaritsky Institute of Geology and Geochemistry of the Ural Branch of RAS), the results are shown in Table 1. To study the trace element composition, a quantity of tourmaline crystals weighed for analysis was ground down into dust and analyzed using the ELAN-9000 instrument. The results are shown in Table 2.

According to the analysis, it can be concluded that the central zone of the crystal of the zoned tourmaline from the Medvedevsky deposit is enriched with magnesium, iron (common iron), sodium, titanium, the edge part is more enriched with calcium. In this case, a gradual increase from the edge to the center was revealed in case of iron; and calcium decreases in the reverse order. The lack of amount is due to the inability to measure light elements.

Figure 2. Pegmatitic vein stripping at the Medvedevsky deposit.
Рисунок 2. Зачистка пегматитовой жилы на Медведевском месторождении.

Figure 3. Zoned tourmaline of the second generation.
Рисунок 3. Зональный турмалин второй генерации.

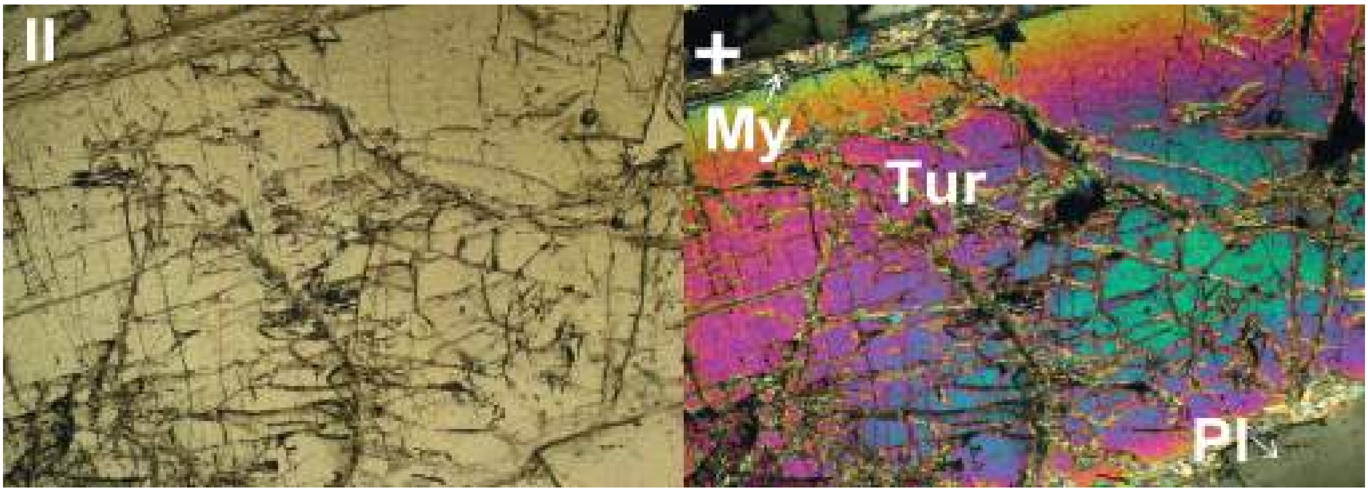

Figure 4. The internal structure of the zoned tourmaline crystal (Tur – tourmaline, My – muscovite, Pl – plagioclase).
Рисунок 4. Внутреннее строение кристалла зонального турмалина (Tur – турмалин, My – мусковит, Pl – плагиоклаз).

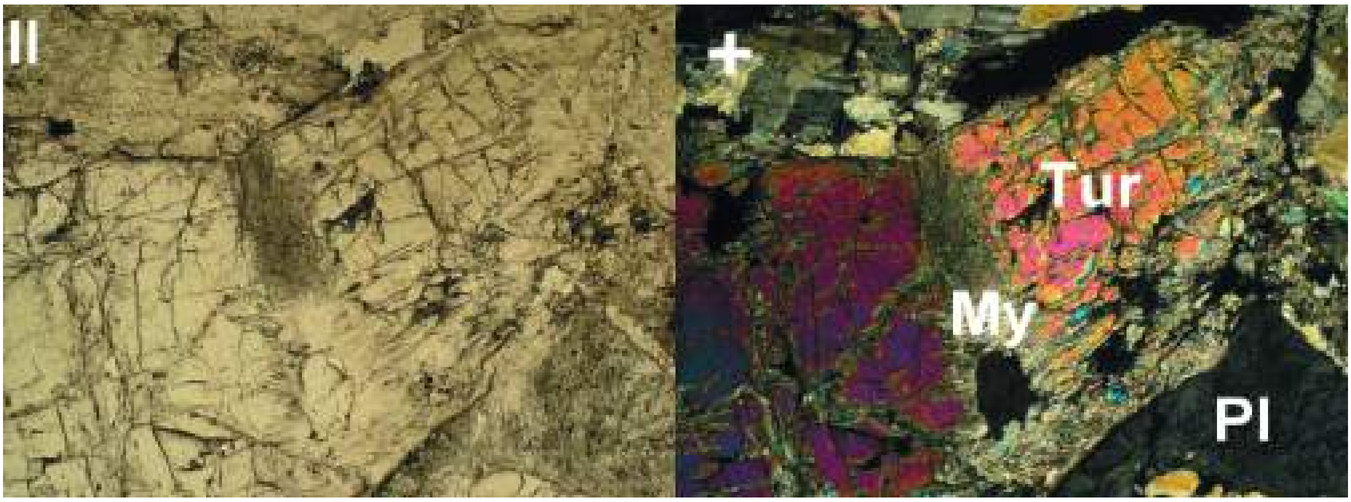

Figure 5. Secondary changes in cracks in tourmaline (Tur – tourmaline, My – muscovite, Pl – plagioclase).
Рисунок 5. Вторичные изменения по трещинам в турмалине (Tur – турмалин, My – мусковит, Pl – плагиоклаз).

Table 1. The composition of tourmaline from pegmatites of the Medvedevsky and Lipovsky deposits.
Таблица 1. Состав турмалина из пегматитов Медведевского и Липовского месторождений.

Point number	The composition of tourmaline													Amount
	SiO_2	TiO_2	Al_2O_3	Cr_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	Li_2O	F	$O{\equiv}F_2$	
Medvedevsky deposit*														
Edge	31.70	0.23	36.71	–	0.56	3.12	–	0.74	1.80	–	2.37	–	–	77.23
Center	33.33	0.39	37.83	–	4.23	3.63	0.41	0.34	2.11	–	2.15	–	–	84.42
Edge	34.18	0.25	39.43	–	0.71	4.57	–	0.53	2.04	–	2.40	–	–	84.11
Point number	The composition of tourmaline													Amount
	SiO_2	TiO_2	Al_2O_3	Cr_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	Li_2O	F	$O{\equiv}F_2$	
*Lipovsky field [5]***														
Edge	39.01	–	40.05	–	0.59	1.76	–	0.60	2.17	0.01	1.46	1.20	–0,51	86.34
Center	38.96	0.04	41.24	0.01	0.10	0.61	–	0.54	2.16	0.01	1.51	1.66	–0,70	86.14
Edge	38.88	–	40.04	–	0.45	1.90	–	0.63	2.13	0.01	1.46	1.20	–0,51	86.19

*The contents of B_2O_3 and H_2O are given according to the theoretical content; the content of Li_2O is calculated according to the crystal-chemical formula.
**The analysis was carried out by the Zavaritsky Institute of Geology and Geochemistry of the Ural Branch of RAS, using Cameca SX 100 micro-analyzer; the analyst is V. V. Khiller; *lithium was determined by ICP-MS [5].

Table 2. The trace element composition of tourmaline from the Medvedevsky and Lipovsky deposits, ppm [5].
Таблица 2. Микроэлементный состав турмалина с Медведевского и Липовского месторождений, г/т [5].

Elements	Deposit		Elements	Deposit	
	Medvedevsky	Lipovskoye		Medvedevsky	Lipovskoye
Li	1355.12	6775.60	La	0.07	0.20
Be	30.11	42.71	Ce	0.24	0.44
Na	0.00	16 710.00	Pr	0.03	0.07
Sc	18.75	0.54	Nd	0.11	0.32
Ti	1656.42	245.42	Sm	0.05	0.10
V	1.95	1.79	Eu	0.01	0.01
Cr	9.28	3.48	Gd	0.07	0.10
Mn	16 977.09	3892.50	Tb	0.02	0.02
Co	1.96	0.49	Dy	0.14	0.11
Ni	9.61	4.30	Ho	0.03	0.02
Cu	14.22	22.33	Er	0.10	0.08
Zn	390.61	82.43	Tm	0.02	0.01
Ga	322.57	228.90	Yb	0.16	0.07
Ge	5.29	9.56	Lu	0.03	0.01
Rb	181.49	17.17	Hf	5.63	0.30
Sr	1.22	21.69	Ta	110.66	2.01
Y	0.63	0.41	W	5.43	0.43
Zr	24.59	9.66	Tl	1.57	0.18
Nb	76.02	1.13	Pb	30.21	149.26
Mo	1.80	0.10	Bi	41.17	386.32
Ag	4.06	0.28	Th	0.29	0.26
Cd	0.17	0.58	U	9.99	0.68
Sn	57.10	6.17	Cs	35.98	12.72
Sb	1.72	29.95	Ba	10.30	39.73

Discussion of results

We can see from Table 1 that the tourmalines of the Medvedevsky deposit are distinguished by a high content of titanium, iron, and manganese. Tourmalines of the Lipovsky deposit are characterized by high concentration of potassium, fluorine. There is a general trend of increasing the content of titanium, aluminum, iron, lithium from the edge to the center and a decrease in calcium in the same direction. The main difference between tourmalines of the Medvedevsky field from similar tourmalines of the Lipovsky field is a high content of manganese and titanium, as well as the complete absence of fluoride in their composition. According to the results of earlier studies, tourmalines of the Lipovsky field belong to fluorine-elbaite one[5–7, 8, 9].

High values of manganese, except for tourmalines of the Medvedevsky deposit, are described in samples from Austria, Zambia, the Czech Republic, Brazil, Tanzania [10–14].

We can see from Table 2 that tourmalines of the Medvedevsky deposit contain high concentration of such elements as zirconium, tantalum, niobium, tungsten, algam, manganese, uranium, and rubidium. This may indicate a rare metal (Ta – Nb) field specialization. Tourmalines of similar composition are described in Madagascar [15].

Conclusion

1. The first detailed mineralogical description of polychromic tourmaline Medvedevsky rare metal deposits (Middle Urals) is given in this paper.

2. Polychromic tourmalines of the Medvedevsky deposit have significant differences from famous Ural tourmalines of the Lipovsky field, both in chemical and trace element composition.

3. The predominance of heavier rare-metal elements in the composition of the tourmaline at the Medvedevsky deposit and the presence of mica replacing tourmaline indicates late overlapped metasomatic processes and more complex formation conditions.

4. The increased content of titanium and manganese, low lithium content and the complete absence of fluorine in the tourmalines of the Medvedevsky deposit relative to the tourmalines of the Lipovsky field indicate a different genesis of the mineral from these places.

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Полихромные турмалины из редкометалльных гранитных пегматитов Медведевского редкометалльного месторождения (Средний Урал)

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Актуальностью работы является уточнение генезиса турмалинов Медведевского редкометалльного месторождения. Для этого в рамках работы было проведено сравнение химического состава и микропримесей турмалинов с уже известными турмалинами Липовского месторождения.
Целью работы является изучение особенностей строения и сравнение химического и микроэлементного состава турмалинов Медведевского месторождения с турмалинами Липовского месторождения.
Методология исследования. Для исследования химического состава турмалина из Медведевского месторождения использовался сканирующий электронный микроскоп Jeol JSM-639LV с приставкой EDS X-max 80. Микроэлементный состав изучался методом ICP–MS на приборе ELAN 9000. Первоначальное описание проводилось с помощью бинокулярного микроскопа МБС-10 и петрографического микроскопа Carl Zeiss.
Результаты. Приведены данные по особенностям строения, химическому и микроэлементному составу полихромного турмалина с Медведевского редкометалльного месторождения.
Выводы. Проведено минералогическое исследование и изучен химический и микроэлементный состав полихромного турмалина с Медведевского редкометалльного месторождения. Проведено сравнение с химическим составом турмалинов из Липовского месторождения.

Ключевые слова: Урал, химический состав турмалина, Медведевское редкометалльное месторождение, пегматиты, Уральские изумрудные копи.

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