Typomorphic features of tourmalines of the Malkhan pegmatite field from the Irkutyanka vein

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This abstract presents the examination results of 5 tourmaline samples found in the Irkutyanka vein of the Malkhan pegmatite field in 2022 (Figure 1). The samples were studied using optical and scanning electron microscopy as well as LA-ICP-MS analyses. Conclusions are made on the chemical composition of the samples, noting the anomalous content of bismuth and lead in the studied samples.

Figure 1. Samples of the studied tourmalines from the Irkutyanka vein of the Malkhan pegmatite field. FOV 6.5 cm.

The Malkhan pegmatite district is among the today active tourmaline deposits, which is the largest source of tourmaline in Russia. The deposit is located in the Krasny Chickoy area of the Zabaikalsky Krai, Transbaikalia, Russia. Geology, mineralogy, and geochemistry of the pegmatite field are described in detail by Zagorsky and Peretyazhko (1992). There are more than 15 tourmaline-bearing veins in the Malkhan pegmatite field including Danburitovaya, Geologicheskaya, Irkutianka, Karkadilovaya, Mokhovaya, Novaya, Oktyabrskaya, Oreshnaya, Skakunya, Solnechnaya, Sosedka, Svetlaya, Tabornaya, Zapadnaya-1 and Zimoveynaya (Zagorskiy *et al.*, 2008).

The Irkutyanka vein has been known since 2018. It is a wedge-shaped body up to 390 m in length and from 5 to 12 m in diameter. The productive part with gem quality tourmaline is represented by an albite and quartz-albite pegmatite. The sizes of miaroles with tourmaline vary widely and have a variety of shapes. The distribution of miaroles and tourmaline in the productive zone is extremely uneven. Tourmaline crystals vary from several mm to 5 cm in size. In addition to the traditional colored varieties of elbaite from Malkhan, we found monochromatic translucent crystals of a light green (mint) color.

The chemical composition of the crystals was analyzed on a TESCAN VEGA 3 scanning electron microscope at an accelerating voltage of 15 kV. Average Li and B contents in each sample were determined using LA-ICP-MS measurements, carried out with an Elan DRC-e quadrupole inductively coupled plasma mass spectrometer. Laser ablation: NWR-213. Calibration was carried out using solid standard samples NIST SRM 610 and NIST SRM 620. The calculation of the elemental content was carried out with normalization to 100% of the sum for oxides.

The tourmaline supergroup has the generalized chemical formula $^{[9]}X^{[6]}Y_3{}^{[6]}Z_6$ ($^{[4]}T_6O_{18}$) ($^{[3]}BO_3$)$_3V_3W$ (Henry *et al.*, 2011) and can be classified into primary groups based on the dominant occupancy of the X-site. Twenty-one members of the tourmaline supergroup contain Na as the dominant cation on the X-site, seven Ca, six □ (vacancy) and only one K.

Occupation of structural positions in chemical formulas was carried out step by step in accordance with the procedure specified in the current nomenclature of tourmalines (Henry *et al.*, 2011). First, Na and Ca were placed in the

X-position. The fraction of a vacancy (□) in this position was calculated from the stoichiometric ratio based on the equation Na + Ca + □ = 1 apfu. The assignment of a particular composition to a specific mineral species was carried out in accordance with the rules on the dominant valence approved by the KNMNK MMA (Bosi *et al.*, 2019). First, based on the predominant component in the X-position, the mineral was determined to belong to the group of alkaline tourmalines (Na> Ca and Na > □) or tourmalines with a dominant vacancy (□ > Na and □ > Ca) (Figure 2).After that, the dominant anion in the W– F–, OH– or O2– position was taken into account. At the last stage, the dominant end-member determining the formula of the end-member of the corresponding mineral species in the tourmaline supergroup was calculated based on the results of the Y-position occupancy.

All the examined tourmalines Contain Li (0.76-0.94 apfu) and Al (7.76-8.11 apfu) in octahedral positions. Other octahedral cations (Mn, Fe, Ti) contain less than 1 apfu. Tourmalines do not show a deficiency of Si (5.90-6.00 apfu) and are represented by species with a predominance of F (0.78-0.83 apfu).

As a result, we have calculated the compositions of tourmalines that fall into the fields of the following two mineral species:
Fluor-elbaite $Na(Li_{1.5}Al_{1.5})Al_6(Si6O_{18})(BO_3)_3(OH)3F$
Fluor-rossmanite $\square(LiAl_2)Al_6(Si_6O_{18})(BO_3)_3(OH)3F$

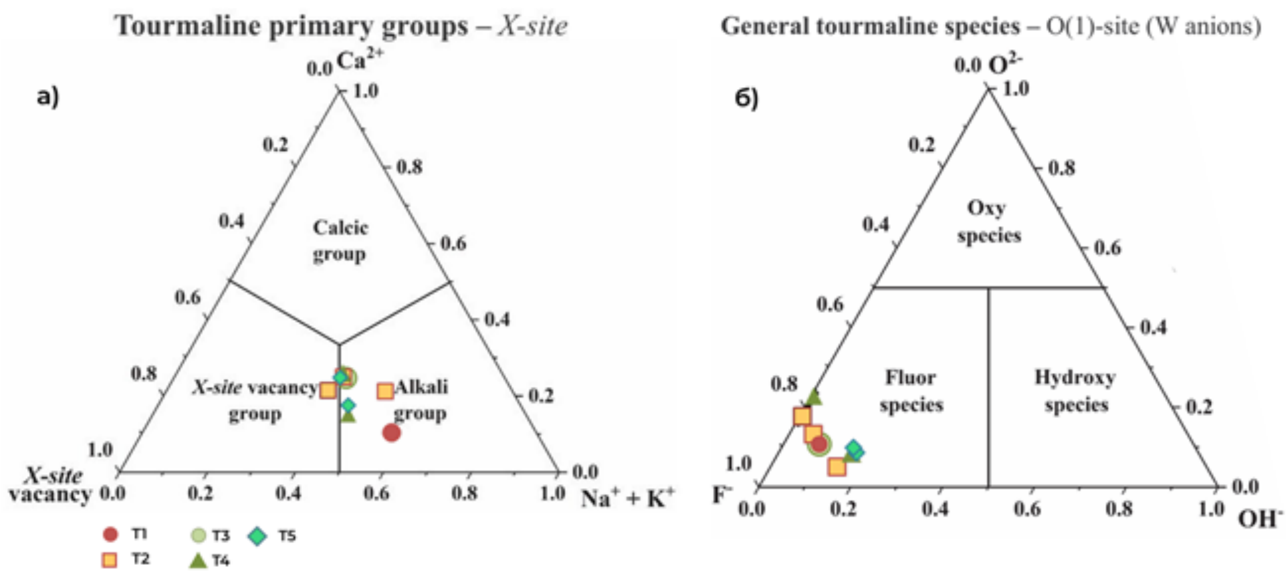

Figure 2.
a) The ratio of cations and vacancies (□) in the X position in tourmaline supergroup minerals from the Irkutyanka vein,
b) The ratio of anions occupying the W position in tourmaline supergroup minerals from the Irkutyanka vein.

It is worth noting that elbaite and fluor-elbaite are common mineral species not only in the Malkhan pegmatite field, but also in other tourmaline deposits. Fluor-rossmanite is endemic to Malkhan and was approved as a new mineral species in 2022. The studied tourmaline samples were found to contain higher lead (up to 0.5 wt.%) and bismuth (up to 0.7 wt.%) contents (figure 3). The largest amount of lead was found in sample T1, and the largest amount of bismuth was found in samples T4 and T5. Bismuth and bismuth-containing minerals have already been described in separate veins on the Malkhan Ridge. The bismuth-columbite mineral was discovered in the Danburitovaya albite-pegmatite vein, and Bi- and Pb-rich tourmalines were found in the Zapadnaya-1 pegmatite vein (Peretyazhko *et al.*, 1989). The lead and bismuth content in our samples may be a typomorphic property. Vereshchagin *et al.* (2022) suggested in their article that trivalent cations can also occupy the X-position of tourmaline. It can be predicted that the general classification scheme for tourmalines based on the occupancy of the X-position will include not only vacancies, monovalent (e.g. Na, K) and divalent (e.g. Ca, Pb) cations, but also trivalent (e.g. Bi) cations. (Vereshchagin et. al. , 2022)

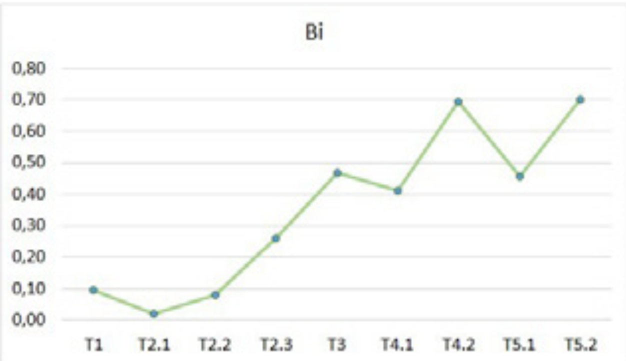

Figure 3. Bismuth content in the studied tourmaline samples in mass percent.

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