FORMATION OF THE SHORL-DRAVITIC HYDROTHERMAL TOURMALINES: ISOTOPE-GEOCHEMICAL CONSTRAINTS

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Midtemperature (300-400^{o}C) hydrothermal propylite and beresite-listwaenite type alterations and related quarts veins often comprise tourmaline of the shorl-dravite series. For instance tourmaline occurs in the Berezovskoe and the Zolotaya Gora Au deposits located in the Central and the South Urals, respectively, in the Shabrovskoe talc deposit located in the Central Urals.

Propylitic and beresite-listwaenitic tourmalines from above deposits is characterized by a linear positive correlation between $Fe_{tot}/(Fe_{tot}+Mg)$ and $\delta^{18}O_{tour}$ ‰ (r=0.89) (Fig. 1). The correlation is caused by an enrichment of mineralizing fluids in ^{18}O as the $Fe_{tot}/(Fe_{tot}+Mg)$ ratio increases. It could be explained by so called "salt effect" that is a great increasing Fe content in fluids during tourmaline crystallization. This correlates clearly with geological environments. Propylitic tourmaline with the low $Fe_{tot}/(Fe_{tot}+Mg)$ ratio crystallized in quartz vein hosted in the talc-carbonate altered rock, whereas that with the high ratio crystallized in quartz veins hosted in altered gabbride. At the same time the beresite-listwaenitic dravite crystallized in the vein hosted in altered ultramafics and gabbride has low $Fe_{tot}/(Fe_{tot}+Mg)$ ratio because it is synchronous with pyrite (Fig. 1).

However there are no experiments on the "salt effect" for the Fe saturated solutions. This provides a discussion on the assumption.

Observed correlation $Fe_{tot}/(Fe_{tot}+Mg)$ vs. $\delta^{18}O_{tour}$ ‰ is suggested to be explained by variability of the CO_2/H_2O ratio in mineralizing fluids. This ratio changes as CO_2 increses. It is illustrated by simple equation:

$$\delta^{18}O_{tour} = \delta^{18}O_{CO2} + \Delta^{18}_{tour\text{-}CO2} + b[(\delta^{18}O_{H2O} - \delta^{18}O_{CO2}) - (\Delta^{18}_{tour\text{-}CO2} - \Delta^{18}_{tour\text{-}H2O})],$$

where $\Delta^{18}_{tour\text{-}CO2}$ и $\Delta^{18}_{tour\text{-}H2O}$ – fractionation factors in the tourmaline-$CO_2(H_2O)$ system, *b* – the CO_2/H_2O ratio in fluid.

Addition of CO_2 with the constant oxygen isotopic composition to fluid determines the $\delta^{18}O_{tour}$ value as a linear function of *b*. If initial fluid is CO_2-bearing then the $\delta^{18}O_{CO2}$ и *b* corrections are necessary.

Good enough interpretation is interrupted by one point fallen out from the $\delta^{18}O$ – $Fe_{tour}/(Fe_{tour}+Mg)$ linear plot (Fig. 1). This fact can be explained only by a local change of $\delta^{18}O_{H2O}$. However a reason of the $\delta^{18}O_{H2O}$ decreasing is difficulty believed all the more so in the same geological environment. This causes additional study of tourmalines.

It is known that above alterations form under different f_{O2} conditions that should be effected the Fe^{3+}/Fe^{2+} ratio in tourmalines. Based on the formula calculations and the Moesbauer data the Fe^{3+} coefficients have been calculated. Figure 2 shows two plots $\delta^{18}O_{tour}$ vs Fe^{3+} (apfu) (a) and $\delta^{18}O_{H2O}$ vs Fe^{3+} (apfu) (b). Correlation factors between $\delta^{18}O_{tour}$ and Fe^{3+} and $\delta^{18}O_{H2O}$ and Fe^{3+} are 0.90 and 0.95, respectively. Positive correlation between oxygen isotopic composition of propylitic and beresitic tourmalines and CO_2 concentration in fluid (the F^{3+}/Fe_{tot} ratio in dravites) reflects the f_{O2} regime of crystallization (fig. 3). Probably in minerilizing fluids there were air O_2 ($\delta^{18}O\approx 23.0$‰) as oxidation agent, initial CO_2 and CO. CO and O_2 interacted to form isotopic heavy CO_2. In turn this led to increasing of the $\delta^{18}O$ value of tourmaline in result of isotopic exchange.

Well known the Emerald mines of the Urals are related to the greisen (zwitter) type alteration. This type of alteration is higher temperature than propylite and beresite-listwaenite. Oxygen isotopic composition and the $Fe_{tour}/(Fe_{tour}+Mg)$ ratio of tourmalines from the Emerald mines and the $\delta^{18}O_{H2O}$ values are close to the propylitic tourmalines from Shabrovskoe and Zolotaya Gora (Fig. 1-2). At the same time the Fe^{3+} content in these tourmalines are much less than in propylitic (Fig. 2) indicating the reduced crystallization conditions.

Conclusions:

1. Isotopic composition of the shorl-dravitic tourmaline from the greisen, propylite and beresite-listwaenite type alterations does not depend on the $Fe_{tour}/(Fe_{tour}+Mg)$ ratio of the tourmalines.

2. Relationship between the $\delta^{18}O$ value and the Fe^{3+} content in tourmalines from barren propylite and gold-bearing beresite-listwaenite is proved. This relationship reflects oxydizing state of mineralizing fluid.
3. Based on the Berezovskoe Au deposit it is shown that altered rock of the beresite-listwaenite type and related quartz veins form under reduced conditions. The low Fe^{3+} value indicates this. In turn low $\delta^{18}O$ value of tourmaline could be considered as an indicator of mineralizing process.

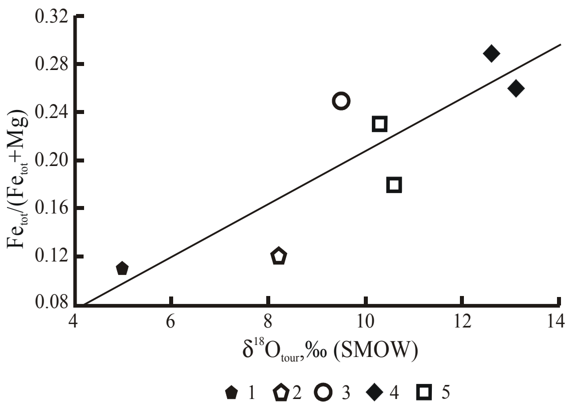

Fig. 1. $\delta^{18}O$ vs $Fe_{tour}/(Fe_{tour}+Mg)$ plot for the hydrothermal shorl-dravitic tourmalines from some deposits in the Urals. 1-2 – Berezovskoe deposit: 1 – beresite-listwaenite, 2 – propylite; 3 – propylite from Zolotaya Gora; 4 – propylite from Shabrovskoe; 5 – greisen (zwitter) from the Emerald mines.

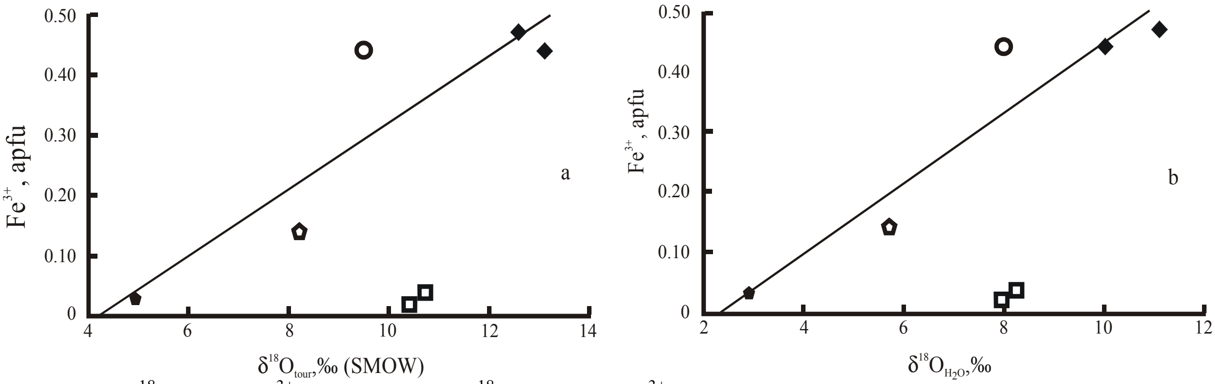

Fig. 2. $\delta^{18}O$‰ vs Fe^{3+}, apfu (a) and $\delta^{18}O_{H2O}$‰ vs Fe^{3+} (b) plots for the hydrothermal shorl-dravitic tourmalines from some deposits in the Urals. See Fig. 1 for legend.

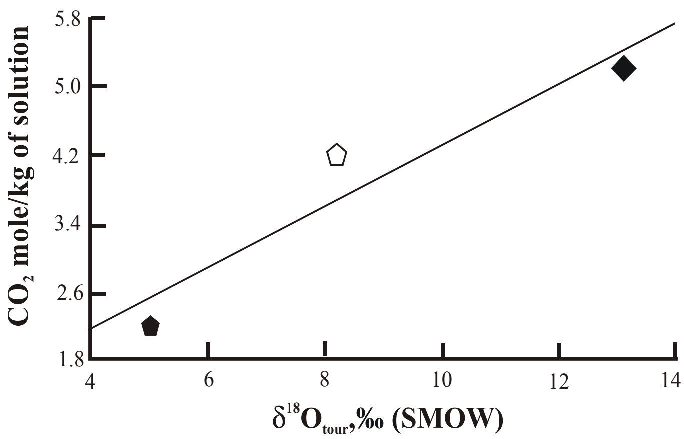

Fig. 3. $\delta^{18}O$‰ vs CO_2 concentration, mole/kg of solution for hydrothermal shorl-dravitic tourmalines from Berezovskoe and Shabrovskoe. See Fig. 1 for legend.

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