MAGMATIC CRYSTALLIZATION OF THE TWO-FELDSPAR-QUARTZ COMPLEX OF LESKHOZOVSKAYA PEGMATITE (SOUTH-EASTERN PAMIR): MELT AND FLUID INCLUSION STUDY

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Introduction

Sub-rare-metal Leskhozovskaya pegmatite intersects the Precambrian gneiss-amphibolite sequence. Feebly marked symmetrical zonality of the pegmatite is manifested toward the center by gradual change from fine-grained oligoclase pegmatite with biotite laths to the two-feldspar irregularly grained pegmatite with abundant tourmaline. The major part is composed of medium-to-coarse-grained oligoclase-orthoclase pegmatite with minor tourmaline, almandine-spessartine garnet, accessory mangancolumbite, and W-rich microlite. Coarse blocks of K-feldspar and quartz are embedded into the two-feldspar matrix and contain numerous small miarolitic pockets. Typical pocket minerals are quartz, orthoclase and multicolored tourmaline. This paper reports the results of melt and fluid inclusion study of quartz from the two-feldspar medium-to-coarse-grained pegmatite.

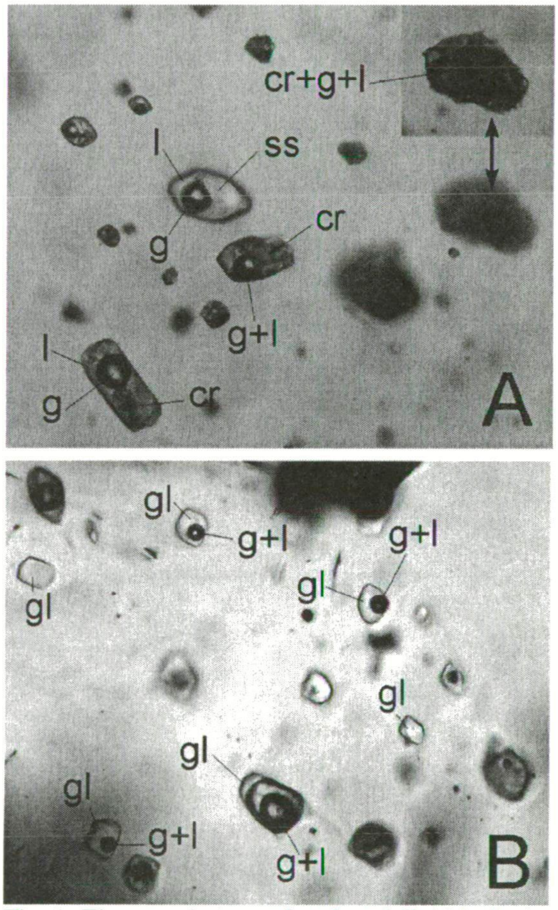

Fig. 1. The associations of melt and fluid inclusions before (A) and after (B) hydrothermal heating at 650°C and 2.5 kbar. g – gas; l – liquid; cr – silicate crystals; ss – sassolite; gl – glass.

Melt and fluid inclusions

The studied quartz contains primary melt (MI) and associated fluid inclusions (FI). The MIs at room temperature (Fig. 1A) consist of silicate daughter minerals and fluid isolations (gas+liquid+sassolite daughter crystal). Typically small (<10 μm) inclusions do not contain visible fluid isolations. Among larger inclusions (10->100 μm), silicate/fluid ratios vary significantly even within a single inclusion group. Re-crystallized silicate portion is composed mostly of F-rich muscovite with elevated Rb, Cs and Li. FIs, which associate with MIs, contain water solution, gas bubble, sassolite, and sometimes unidentified daughter crystals. Micro-thermometric study revealed that FI and MI's fluid isolations of the same group have similar eutectic, ice-melting and sassolite-dissolution temperatures. According to micro-thermometric data, concentrations of H_3BO_3 are estimated at 12-16 wt. % -- both for fluid inclusions and fluid isolations. Several unidentified daughter crystals in some fluid inclusions dissolve within 150-310°C. Homogenization of MI's fluid isolation was observed at 250-270°C, while total homogenization of associated fluid inclusions occurs mainly within 220-270°C interval. Meanwhile, there are rare fluid inclusions that homogenize at 310-350°C.

To prevent leakage of volatiles, the samples containing melt inclusions have been heated under hydrothermal conditions in rapidly quenched autoclave at 500, 550, 600 and 650±10°C and 2-2.5 kbar for 14-24 hours. The first indications of melting have been observed in the MIs after the quench at 550°C. Small (<10 μm) homogeneous melt inclusions appeared after the run at 600-615°C. After the run at 650°C (Fig. 1B) along with larger (~10-15 μm) homogeneous melt inclusions, we have observed inclusions containing glass, un-melted crystals and fluid isolations. The latter consist of liquid, gas bubbles and daughter sassolite crystals. Fig. 1B shows that glass/fluid ratio varies significantly within the same group of heated MIs.

Fluid isolations after hydrothermal experiments at 650°C have higher homogenization temperatures (up to 330°C), while eutectic, ice-melting and sassolite-dissolution temperatures remain similar to the unheated-inclusion ones. This indicates proportional dissolution of fluid components in the melt during the heating.

Composition of MI's glasses

The MI's glasses are low-silica and per-aluminous (ASI – 1.1 to 1.2) according to their major-element composition, measured using electron microprobe (EMPA) method. K dominates the alkaline metals at elevated total alkali content (8-9 wt. %). F (1.98 – 3.07 wt. %), H_2O (5.63 – 6.18 wt. %) and B_2O_3 (up to 2.4 wt. %) dominate the volatile components, while P and Cl are negligible. SIMS data demonstrate that MIs are strongly enriched in Li (2711 ppm), Be (154 ppm) and, to a lesser degree, in Ta (72 ppm) and Nb (74 ppm). Concentration of Sn and W appear to be below the detection limits of SIMS. No significant differences in glass compositions were detected for totally homogeneous inclusions and inclusions containing glass and fluid isolations. This suggests that the inclusions are a result of the heterogeneous entrapment rather than that of the liquid immiscibility. Even after combination of EMPA and SIMS data, analytical totals remain below 100%. This means that some elements could be lost under electron and ion beams. It is known that Na and H_2O are the most mobile components of hydrous glasses, especially under electron beam. To avoid significant underestimation of Na, we performed our EMPA analyses at low (10 nA) beam current with the beam defocused to 20 µm. Therefore, water remains the only component that could have been lost. Previous works indicate (Ihinger et al., 1994) that water could be underestimated by SIMS at concentrations >5 wt %. Assuming that, the water content in studied melt inclusions can be estimated at 19 wt. %.

Discussion and conclusions

Primary melt and fluid inclusions in the quartz of the two-feldspar pegmatite provide important information about the P-T-X conditions of magmatic crystallization of Leskhozovskaya pegmatite. Taking into account varying silicate/fluid ratios of MIs and similarity of glass composition for totally homogeneous MIs and MIs that consist of glass and fluid isolation, we conclude that the studied complex have crystallized from heterogeneous mixture of the silicate melt and boric acid-water fluid. The strong enrichment in alkaline rare metals (Li, Rb, Cs), volatiles (F, B, H_2O) and some ore metals (Be, Ta, Nb) indicate deeply evolved nature of the melts. The major element compositions of the studied melt inclusions are close to those reported by (Thomas et al., 2003) for Sn-rich pegmatites of Ehrenfriedersdorf, Germany, and by (Smirnov et al., 2003) for sub-rare-metal miarolitic pegmatite of Malkhan ridge. Apparently, the major-element compositions of studied melts are common for highly evolved magmatic systems with rare-metal specialization. Meanwhile, the melts forming two-feldspar pegmatite of Leskhozovskaya vein differ strongly from Sn-rich pegmatites of Ehrenfriedersdorf (very low Sn and W contents and high Ta and Nb). The enrichment in Ta and Nb, and depletion in Sn and W make these melts similar to the latest melts, represented by inclusions from pocket quartz of Oktyabrskaya pegmatite mine in Malkhan ridge. High K/Na ratios are common for inclusions from reported pegmatite localities probably due to crystallization of Na-rich plagioclase at these stages. However, ratios of alkalis, especially of Rb and Cs are highly variable and show no similarity. One of the most striking features of the studied melts is very low concentrations of Cl and P along with high H_2O, F and B contents. The strong depletion in Cl and P is a feature common for the latest melts of Oktyabrskaya mine. This feature discriminates the melts of the Leskhozovskaya vein from those of Ehrenfriedersdorf Sn-rich pegmatite. Thus, we conclude that the two-feldspar medium-to-coarse-grained pegmatite crystallized from hydrous per-aluminous silicate melt, enriched in F, B and some rare alkaline and ore metals, similarly to some other pegmatites. The reported data display great variability in trace- and minor-element concentrations for late portions of the highly evolved pegmatitic magmas.

The studied MIs were trapped within 600-650°C temperature range and have crystallized down to about 550°C. Using the data on PVTX-modeling of boric-acid fluids by (Peretyazhko, Zagorsky, 2002) and our micro-thermometric data, we can estimate that as the temperature decreases from 615 to 550°C during the crystallization of the entrapped melt, the pressure increases from 2.2-2.8 to up to 3.8 kbar.

References

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