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FLUID INCLUSIONS STUDY OF QUARTZ-TOURMALINE VEINS ASSOCIATED WITH EMERALD MINERALIZATION, KAFUBU AREA, ZAMBIA

ZACHARIÁŠ, J.[1], ŽÁČEK, V.[2], HRSTKA, T.[1], MIHALJEVIČ, M.[1]
[1] Charles University in Prague, Institute of Geochemistry, Albertov 6, CZ-128 43 Prague 2, Czech Republic.
[2] Czech Geological Survey, Klárov 3, CZ-118 21 Prague 1, Czech Republic.
E-mail: zachar@natur.cuni.cz

During the last two decades, Zambia has become a world-class emerald producing country. The whole Zambian emerald production, amounting to about 15 % of world production, comes form the Kafubu Area (Ndola Rural Area), south of the Copperbelt. The Kafubu Emerald Area covers ca. 200 km^2 and includes several tens open cast mines and prospecting pits. In 2001, a project of the Czech Geological Survey was realized, comprising complex study of emerald mineralization in the Kafubu area (Seifert et al. 2002, in print).

In the Kafubu area, the high-grade metamorphic rocks of the Basement Palaeoproterozoic Complex are overlain by Mesoproterozoic Muva Supergroup (metaquartzites, quartz-mica schists, amphibolites and Mg-rich metabasites) and by Katanga Supegroup (Meso-Neoproterozoic in age). The rocks hosting the emerald mineralization occupy a lower-middle part of the local Muva sequence. The gemstone-quality emeralds occur mostly in up to 2 m thick reaction zones of phlogopite-rich rocks along contacts of quartz-tourmaline veins and pegmatites with metabasic rocks. Granitic quartz-feldspar-muscovite pegmatites (usually only up to 20m in width) occur in the area of approximately 2 x 10 km ("Kafubu pegmatite field" of Seifert et al. in print). Three types of quartz-tourmaline veins were distinguished: 1) quartz-tourmaline rocks ("veins") concordant with lithological layering; 2) quartz-tourmaline (beryl, muscovite) veins both discordant and semi-concordant with lithological layering; 3) late "alpine-type" quartz-tourmaline veins (of local occurrence).

Fluid inclusions were studied in 12 samples from various types of quartz-tourmaline±beryl veins. Ambiguous primary inclusions were only identified in some beryl crystals. The primary inclusions in tourmaline are scarce, while the primary character of inclusions in quartz is questionable, as most of them seem to be rather pseudosecondary than primary. Several generations (usually up to three) of secondary inclusions are quite common in all studied minerals.

In general, three following types of fluids were recognized: aqueous-only, aqueous-carbonic and carbonic. The first two types can be further subdivided with respect to the salinity into low, moderate and high-salinity subgroups. The carbonic fluids were identified in two samples only, and are clearly of secondary origin. The aqueous-only and aqueous-carbonic fluids were found in all samples of all genetic types of fluid inclusions, the second type being significantly more common in quartz than in tourmaline.

The following fluid inclusion types were identified in the studied samples: 1) two or three phase liquid-rich H_2O-CO_2 inclusions; 2) two or three phase vapor-rich H_2O-CO_2 inclusions; 3) one phase liquid-rich CO_2 inclusions; 4) multiphase liquid-rich H_2O-CO_2 inclusions with 1-2 solid translucent phases (one of them is usually cubic); 5) two phase liquid-rich H_2O inclusions; 6) multiphase liquid-rich H_2O inclusions with 1-2 solid translucent phases (one of them is usually cubic) and 7) monophase liquid H_2O inclusions.

The early fluids in quartz are always of aqueous-carbonic type, while the late ones are of aqueous-only type. In contrast to quartz, in beryl and in tourmaline, all inclusions are usually aqueous-only. However few beryl samples with extremely rare aqueous-carbonic inclusions of uncertain origin was identified also. The aqueous-carbonic inclusions in tourmaline were always secondary.

The aqueous-carbonic inclusions homogenize mostly to the liquid state. The highest observed total homogenisation temperatures correspond to 420-410 °C (quartz) and 330 °C (beryl). The inclusions frequently decrepitated at 2 to 20 °C, either before or after the total inclusion homogenisation. The homogenisation temperatures of H_2O-only fluids display four well-shaped peaks at 370-350 °C, 300-280 °C, 230-210 °C and 160-130 °C. They are believed to represent four separate fluid fluxes. Primary and pseudosecondary aqueous-only inclusions in beryl and tourmaline homogenize mostly at 230-220 °C, and several measurements are randomly scattered up to 370 °C (beryl) and 320 °C (tourmaline).

The salinity of the aqueous phase (of H_2O-only and H_2O-CO_2 fluids) is estimated to 0-1, 5-8, 15-17, 23-25 and 34-35 wt. % NaCl eq. The most common first melting temperatures (from –57 to –47 °C) indicate presence of H_2O-$NaCl$-$CaCl_2$ salt system. The preliminary results of single inclusion analyses by LA-ICP-MS demonstrated the presence of Na, Ca, K, Fe and Sr cations. The daughter phases from multiphase inclusions correspond to NaCl, KCl and $CaCl_2$ (based on EDX-spectra).

The CO_2-phase of fluid inclusions homogenize mostly from +26 to +31 °C, both to liquid and vapor. The solid CO_2 melts mostly from –56.6 to –56.7 °C and less frequently from –57.4 to –57.6 °C. The maximum total $CO_2 \pm CH_4 \pm N_2$ content of aqueous-carbonic fluids is estimated to 25 mol. % and decreases with time to about 4-3 mol. %. The N_2 or CH_4 admixture in the gaseous phase is generally very low (0-2 mol. %) and only exceptionally is higher (10 mol. % of N_2, or 3 mol. % of CH_4).

The possible trapping conditions correspond to 400-450 MPa at ~400 °C and 150-350 MPa at ~400 °C for the older and younger generations of quartz-tourmaline veins respectively. The P-T-X data of primary fluid inclusions, in combination with other geological, mineralogical and geochemical information's, allow us to suggest formation of quartz-tourmaline veins and associated emerald-bearing phlogopitization as a product of fluids expelled from a hidden body of a fertile granite that is, on a regional scale, manifested by numerous pegmatite dykes ("Kafubu pegmatite field" of Seifert et al., 2002, in print).

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