Significance of Zr-in-rutile thermometry for deducing the decompression *P–T* path of a garnet-clinopyroxene granulite in the Moldanubian Zone of the Bohemian Massif

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This work aims to show the importance of Zr-in-rutile thermometry for evaluating the *P–T* history of granulite facies rocks, where higher diffusion rates in the main constituent minerals impede the use of geothermometers based on element distributions. We apply Zr-in-rutile thermometry to a garnet-clinopyroxene (Grt-Cpx) granulite from the Moldanubian Zone of the Bohemian Massif. Three major metamorphic evolutionary stages are identified from the Grt-Cpx granulite. The early high-pressure (HP) stage is represented by an inclusion assemblage in garnet: a high-Ca garnet core (32–38 % grossular, 30–32 % pyrope and 32–35 % almandine) + omphacite (36–39 % jadeite and 3–5 % Ca-Tschermak) + plagioclase (18 % anorthite) + pargasitic amphibole + rutile + zircon + quartz. The subsequent medium-pressure (MP) stage is represented by matrix minerals composed of augitic clinopyroxene (2–6 % jadeite and 2–6 % Ca-Tschermak) + orthopyroxene + ternary feldspar (17–23 % anorthite, 41–44 albite, 33–43 % orthoclase; re-integrated compositions from antiperthite grains in the matrix) + rutile + ilmenite + quartz. The final low-pressure (LP) stage is represented by a symplectic corona composed of calcic plagioclase (~90 % anorthite) + orthopyroxene + magnetite. Application of Grt-Cpx and/or jadeite-quartz-albite geobarometers gives pressures of ~1.8 GPa for the early HP stage and 1.3–1.4 GPa for the MP stage. The final LP stage is constrained to lower than ~0.7 GPa using conventional geothermobarometers. Rutile inclusions in high-grossular garnet have a rather low and limited range of Zr contents (mostly 1100–1500 ppm), regardless of inclusion size. This suggests that rutile inclusions preserved the initial Zr compositions without much modification by later re-equilibration. Application of Zr-in-rutile thermometry yields a temperature of ~830°C at ~1.8 GPa for the early HP stage of granulite evolution. Rutile grains in undeformed clinopyroxene-rich domains of the matrix generally occur as small euhedral crystals and have higher Zr contents (mostly 8000–10000 ppm), corresponding to 980–1066°C at 1.35 GPa using Zr-in-rutile thermometry. In contrast, those in strongly deformed quartz-rich domains of the matrix occur as coarser and more elongated grains with lower Zr contents (3000–5000 ppm), yielding slightly lower temperatures due to retrogressive re-equilibration. Based on these results, we reveal that the studied Grt-Cpx granulite underwent a significant heating by about 200°C during the early stage of decompression from the peak pressure. SHRIMP U-Pb dating for the zircon inclusions in high-grossular garnet indicate that the HP stage of the studied granulite occurred at c.340 Ma, which is indistinguishable to reported LP zircon ages from South Bohemia. Thus, the studied granulite was rapidly heated and exhumed from mantle depth to middle to upper crust in a short period. This rapid heating associated with exhumation was caused by incorporation of the Grt-Cpx granulite into higher temperature felsic granulites which exhumed from deeper parts of the continental collision zone.

Keywords: Zr-in-rutile thermometry, garnet-clinopyroxene barometry, high-pressure granulite, continental collision zone, Bohemian Massif

