

Rutile inclusions in quartz crystals record decreasing temperature and pressure during the exhumation of the Su-Lu UHP metamorphic belt in Donghai, East China

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ABSTRACT

Donghai County in the Jiangsu Province of East China is known for its large-scale production of high-quality quartz crystals. The quartz crystals are hosted within the Su-Lu ultrahigh-pressure (UHP) metamorphic belt. They form in quartz veins hosted by eclogite and gneiss, or along contacts between eclogite and gneiss and are mined as placer deposits in the Quaternary sediments. Backscattered electron imaging of the rutile in rutile-bearing euhedral quartz crystals from this region reveal three compositionally and texturally distinct generations of rutile, encapsulated within the host quartz crystal. The earliest generation of rutile (R1) is brightest in BSE, reflecting enrichment in Fe₂O₃ (0.75–2.08 wt%), Nb₂O₅ (0.37–0.93 wt%), WO₃ (0.48–2.99 wt%), and ZrO₂ (0.005–0.105 wt%), relative to R2 and R3. R2 rutile overgrows R1 rutile and contains 0.66–1.11 wt% Fe₂O₃, 0.45–0.74 wt% Nb₂O₅, 0.09–0.20 wt% WO₃, and <0.001–0.013 wt% ZrO₂. R3 rutile, which is the only rutile generation in contact with the host quartz crystals is darkest in BSE and always overgrows R1 and rounded aggregates of R2. R3 rutile contains 0.40–0.68 wt% Fe₂O₃, 0.13–0.37 wt% Nb₂O₅, 0.03–0.12 wt% WO₃, and <0.001 wt% ZrO₂. Oxygen isotopes decrease progressively from 0.6 to –1.5‰ in R1 rutile to 0.1‰ in R2 rutile to –5.1 to –0.3‰ in R3 rutile, consistent with decreasing temperature of rutile crystallization.

Combined application of the Zr in rutile and Ti in quartz thermobarometers indicate that these rutile generations precipitated at progressively lower pressures and temperatures, consistent with previously determined retrograde metamorphic conditions of the Su-Lu UHP belt. R1 grew after peak metamorphism during retrograde eclogite facies metamorphism at temperatures between 720 and 800 °C and pressures between 21.7 and 26.6 kbar. During subsequent retrograde metamorphism, R1 was fractured and partially brecciated and overgrown by R2 during epidote-amphibolite facies retrograde metamorphism in the range of 400 to 500 °C and 5 kbar. Zirconium concentrations of <14 ppm in R3 rutile and Ti concentrations of <1 ppm in the co-precipitated host quartz suggest that they both grew at low temperatures of <300° and pressures <2 kbars. Oscillatory growth zones in quartz revealed by cathodoluminescence suggest that no subsequent metamorphism or hydrothermal activity occurred after the formation of the host euhedral quartz crystals and is consistent with a low temperature of quartz crystallization. The random distribution of rutile crystals in the quartz and the lack of evidence for rutile transport by hydrothermal fluids indicate that the host quartz formed by a dissolution-replacement process, whereby the original host mineral, likely omphacite or garnet, was replaced by quartz, but the rutile was not significantly replaced or dissolved due to the low solubility of Ti in low-temperature hydrothermal fluids.

Keywords: Rutile, oxygen isotope, SEM-CL, Su-Lu ultrahigh-pressure metamorphic belt, Donghai, Ti in quartz, Zr in rutile, thermobarometer