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Laser Raman microspectrometry of metamorphic quartz: A simple method for comparison of metamorphic pressures

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Abstract

A Laser Raman microspectrometry method was applied to metamorphic quartz in quartz-eclogite-, epidote-amphibolite-, and amphibolite-facies rocks to assess the quantitative correlation between the Raman frequency shift and metamorphic pressure. Quartz crystals sealed in garnet and other phases have a higher frequency shift than those in the matrix. Furthermore, the quartz inclusions show a frequency shift specific to the individual host crystals in eclogites (garnet ≈ kyanite > omphacite ≈ epidote). These observations imply that the residual pressures retained by quartz inclusions depend on elastic parameters of the host crystals, as discussed by previous researchers. The Raman frequency shift of quartz inclusions in garnet systematically increases with increasing peak metamorphic pressures from the amphibolite facies (0.30–0.55 GPa/470–570 °C), through the epidote-amphibolite facies (0.8–1.1 GPa/470–635 °C) to the quartz-eclogite facies (2.1–2.5 GPa/660–710 °C). Calibrations based on experimental work suggest that the measured Raman frequency shifts signify residual pressures of 0.1–0.2, 0.4–0.6, and 0.8–1.0 GPa for these three groups of metamorphic rocks, respectively. Normal stresses (internal pressures) of quartz inclusions in garnet, numerically simulated with an elastic model, and inferred pressure-temperature conditions at peak metamorphic stage are compatible with the residual pressures estimated from the frequency shifts. Laser Raman microspectroscopic analysis of quartz is a simple and effective method for (1) comparison of pressure conditions in metamorphic rocks formed under various pressure-temperature conditions, and (2) detection of a higher-pressure signature in metamorphic rocks extensively recrystallized during the subsequent exhumation and hydration stage.

Keywords: Raman shift, quartz, residual pressure, metamorphism, elastic model