Raman spectroscopy of quartz eclogite in the Sanbagawa metamorphic belt: Potential of Raman geobarometry using kyanite-quartz system

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The pressure–temperature conditions of metamorphic rocks have been estimated by using thermodynamic models based on the chemical equilibrium between coexisting minerals. Recently, the development of a new method called “Raman geothermobarometer” has been progressing. It applies Raman spectroscopy and focuses on the residual pressure of the inclusion minerals. In particular, “garnet-quartz Raman barometer” using quartz inclusions in garnet has been proposed as a useful technique, which estimates residual pressure from peak shift of Raman spectrum and converts to metamorphic pressure (Enami et al., 2007_AM; Kouketsu et al., 2014_AM). On the other hand, the host garnet forms a solid solution, and each end member has different physical parameters. Therefore, theoretical errors occur between the actual measurement value and the numerical calculation assuming garnet as an end member. In this study, we verified a new Raman geobarometer using kyanite instead of garnet. Neither kyanite nor quartz forms a solid solution, and kyanite is stable under a wide pressure and temperature range. Hence, the kyanite-quartz system may be applicable to various high-pressure metamorphic rocks.

The samples used in this study are quartz eclogites from the Gongen region in the Sanbagawa metamorphic belt, central Shikoku, southwest Japan. The peak metamorphic pressure–temperature condition of the Gongen quartz eclogite was estimated to be 2.3–2.4 GPa/675–740 ℃, which is the highest pressure in the Sanbagawa metamorphic belt in central Shikoku (Miyamoto et al., 2007_JMPS). In this study, five quartz eclogite samples were collected from one location on the ridge of Mt. Gongen and two locations along the Tokonabedani valley. Two quartz eclogite samples described by Miyamoto et al. (2007) were also analyzed. For each sample, Raman spectroscopic analyses were performed on thick sections (about 100 μm thick) and only quartz inclusions completely encapsulated in kyanite were analyzed. All Raman spectra of 237 quartz inclusions in kyanite showed a peak shift toward higher wavenumber sides indicating compressive stress. residual pressure values calculated from the peak shift showed a wide range of 0.16–0.89 GPa. In order to evaluate the factor of the variation in residual pressure, the inclusion diameter was measured, but no significant correlation was found with the residual pressure. Raman mapping was performed to confirm the distribution of the residual pressure inside the inclusion, but it is homogeneous except grain boundary. Therefore, the following possibilities are considered as the factors of the variation in residual pressure: (1) quartz inclusions were trapped in kyanite at wide pressure–temperature range, (2) effect of healed crack in host kyanite during exhumation.The peak metamorphic condition was calculated based on the maximum residual pressure of 0.89 GPa using a numerical model, and the result shows in good agreement with previously estimated range by using the thermodynamic modeling (Miyamoto et al., 2007). This result suggests that kyanite had been growing during the Sanbagawa peak metamorphic condition. Additionally, calculations using the maximum values at each sampling locations also show good agreement with the metamorphic range reported by the previous study, and thus Gongen quartz eclogite is thought to have subducted extensively to the deepest depth of the Sanbagawa metamorphism.

This study indicates that kyanite can be used as a host mineral like garnet, and the kyanite-quartz system can estimate the peak pressure–temperature condition. However, some unverified points remain such as the effect of the elastic anisotropy of kyanite and quartz, and the possibility of underestimating the metamorphic conditions by selecting the highest value from the few measurement results. In the future, research will be conducted toward the development of a highly reliable geothermobarometer based on these improvements.

Keywords: Raman spectroscopy, geobarometer, high-pressure, kyanite, quartz

