Detection of zircon growth pulses and thermal evolution of Ryoke complex

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Zircon growth pulses in high-temperature metamorphic rocks and coeval plutonic rocks of the Ryoke complex were detected by a statistical model for multiple discrete growths. The model assumes rapid growth of zircon in comparison with analytical errors. Zircon U-Pb ages x_j (j = 1, 2, 3, ,,, n; n is number of data) and their analytical errors s_j were used as input data for the numerical simulation of the model. The numerical simulations of the statistical model were performed by Hamiltonian Monte Carlo (HMC) sampling, and yielded optimized values of ages of growth pulses m_i (i = 1, 2, 3, ,,, k; k is number of growth pulses) and their proportions p_i. The adequate k was evaluated by information criterions, such as Akaike's Information Criterion (AIC), Bayesian Information Criterion (BIC) or etc.

Two pelitic migmatites and three gneissose tonalites from the Mikawa Ryoke, central Japan, and one pelitic migmatite from the Yanai Ryoke, southwest Japan, were used for the detection of zircon growth pulses. The pelitic migmatites were collected from the lower and middle units. Their *P*-*T* conditions are 5.7 kbar and 801 deg C (the lower unit) and 4.3 kbar and 715 deg C (the middle unit), respectively (Miyazaki, 2010). Three gneissose tonalites from the Mikawa area intruded into lower unit. One pelitic migmatite (6.4 kbar and 850 deg C) from the Yanai area was collected from the highest metamorphic pressure and temperature area forming dome-like structure (Ikeda et al., in preparation). Diffusion-controlled growth kinetics of metamorphic zircon were determined by the method proposed by Miyazaki et al. (2018). High-pressure and high-temperature experiments of diffusion-controlled zircon dissolution show that dissolution of 50 micron zircon in hydrous felsic melt requires only 100 year at 750 deg C (Harrsion and Watson, 1983). Reversely, growth of 50 micron zircon also requires only 100 year at the same conditions other than positive supersaturation S =1.We estimate upper bound of duration of zircon growth in hydrous melt using formulation of diffusion-controlled Ostwald ripening (Miyazaki et al., 2019). The supersaturation of Ostwald ripening with 10 micron critical size is $S = 2 \times 10^{-4}$, 10 micron overgrowth on 50 micron core requires about 2×10^5 year. Even if effective diffusion coefficient in pelitic migmatite is 10 times smaller than that in melt, the growth duration is short time similar to U-Pb analytical error.

Our results show that two pelitic migmatites in the Mikawa area have three growth pulses, such as ca. 100 Ma, ca 90 Ma, and ca 75 Ma. Conventional U-Pb spot analysis of the pelitic migmatite of the upper part yielded only ca. 100 Ma and ca. 90 Ma pulses. However, single-shot laser ablation ICP-MS U-Pb dating of invisible outer-rim of zircon (Iwano et al., 2020) revealed ca. 75 Ma growth pulse. U-Pb zircon ages from three gneissose tonalites show two or three pulses around ca. 75 Ma. Interval of growth pulses in gneissose tonalites (3-7 Myr) is shorter than those of metamorphic growth (10-15 Myr). One pelitic migmatite from the Yanai area yielded five zircon growth pulses, such as ca. 107 Ma, 103 Ma, 99 Ma, 97 Ma, and 93 Ma. Number of pulses and interval of pulses in the Yanai migmatites are larger (five pulses) and shorter (2-4 Myr) than those in the Mikawa migmatites. Our statistical model revealed that multiple growth pulses of zircon occurred in the Ryoke complex in the Mikawa and Yanai areas. Field observations suggest that zircon growth associated with developments of migmatites and/or coeval intrusions of gneissose tonalites. It is suggested that generation of growth pulses may related to advection of melt and releasing latent heat during solidification of melt. The melt advection and solidification may control thermal evolution of the high-*T* Ryoke complex.

Keywords: metamorphic reaction, zircon, metamorphic age, growth model, U-Pb dating, Ryoke