Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SMP09-04 会場:201A 時間:5 月 27 日 10:00-10:15

領家変成帯における高温作用の継続時間推定とミグマタイト中でのジルコン/ザクロ石間の REE 分配
Duration of low-P/T type metamorphism and zircon/garnet REE partitioning in migmatites, Ryoke metamorphic belt, Japan

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Duration of low-pressure/high-temperature type, upper amphibolite to granulite facies Ryoke metamorphism is estimated by SHRIMP zircon U-Pb dating. Zircon in migmatites (up to ca. 800^{o}C, ca. 0.5 GPa) has inherited core and metamorphic rim, and between them is a dark-cathodoluminescence (dark-CL) annulus with melt (glass) inclusions (Kawakami et al., 2013). The rim shows variation in age from ca. 95.5 Ma to 88.7 Ma, suggesting the duration of hypersolidus high-temperature condition for ca. 7 Myr. Zircon rims with old ages tend to show steeply positive HREE patterns whereas the young zircon rims tend to show less steeply positive HREE patterns. Ti content in zircon rims are low, ranging from 1.23 to 2.25 ppm. This small variation in Ti content may imply narrow temperature range of zircon rim formation.

Garnet in the same sample has zoning in trace elements, and REE and Y contents are high in the core and lower towards the rim, suggesting prograde growth of this garnet. Garnet shows steeply positive HREE patterns at the core whereas it becomes less steep at the rim. Zircon grains with dark-CL annulus with um-sized inclusions are also included in the garnet, and judging from the mixed analysis of thin zircon rim and core, these inclusion zircon also has rims with steeply positive HREE patterns. This suggests that the inclusion zircons also have the rim that grew during the prograde, melt-present stage of the Ryoke metamorphism, but has the steeply positive HREE patterns even though they likely grew simultaneously with garnet in the presence of melt.

Systematic change of REE patterns in garnet and in zircon rim described above suggests that availability of HREE decreased as zircon grew, because of the simultaneous growth of garnet. In spite of this, D_{REE}(garnet/zircon) does not show flat pattern nor approach unity for HREE (e.g., Rubatto, 2002), showing different trend from the cases in the UHT rocks. Possible controlling factors of D_{REE}(garnet/zircon) include (i) difference in pressure and temperature conditions, (ii) difference in garnet composition, especially in grossular content (Taylor et al., 2014), (iii) effect of self-diffusion of garnet trace element compositional profiles under UHT conditions (Buick et al. 2006), and (iv) different timing of zircon and garnet growth (Buick et al. 2006). Among the possible controlling factors of the difference of D_{REE}(zircon/garnet) from UHT examples discussed above, (ii) can be neglected because garnet in this study has low grossular content (0.02-0.03) but showing the steep HREE pattern. Factor (iii) is not likely because our garnet preserves zoning in trace elements and even the high-Y annulus is preserved. Factor (iv) is also not likely from the above-mentioned observations that support simultaneous growth of zircon and garnet. Therefore, the temperature condition could be the most likely factor to control D_{REE}(garnet/zircon), although an example of Whitehouse and Platt (2003) who reported the flat D_{REE}(garnet/zircon) pattern near unity does not fit this interpretation. Our example suggests that it can be misleading to judge timing of 'normal' granulite facies metamorphism solely from the D_{REE}(garnet/zircon) pattern on the assumption that D_{REE}(garnet/zircon) becomes unity when garnet and zircon coexisted.

キーワード: 高温変成作用, 部分溶融, ジルコン, ザクロ石, 希土類元素
Keywords: high temperature metamorphism, partial melting, zircon, garnet, rare earth elements