Isotopic change and its homogenization for petrogenesis of the Busetsu granites in Japan: evidence from multiple isotope micro-analyses

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The Busetsu granite pluton in Aichi, Japan is one of the Ryoke granites. The Busetsu granite pluton is unique in S-type granite affinity within the Japan arc where I-type granites are dominant in the Japan arc. This peraluminous composition has been interpreted as a result from contributions of sedimentary component (e.g., Sato and Nakai, 1991; Ishihara and Chappell, 2007). However, most previous studies focused on the variation in whole-rock chemical compositions within the pluton. Although whole-rock chemical and isotopic analyses are essential for petrogenetic interpretation, they only provide the accumulated information of various minerals that have undergone different magmatic histories. Chemical and isotopic micro-analyses of individual grains are essential to trace the magma evolution during the consolidation of granitic body.

In this study, we conducted conventional whole-rock geochemical analyses (major and trace elements and isotope compositions) for seven rock samples from the Busetsu pluton using a x-ray fluorescence (XRF) analyser and an inductively coupled plasma mass spectrometers (ICPMS). The chemical compositions of plagioclase and monazite in these samples were determined by an electron microprobe analyser and a laser ablation-ICPMS (LA-ICPMS). The micro-analyses of Sr and Nd isotopes in plagioclase and monazite were carried out using a LA-multi collector-ICPMS. Further, U-Pb dating of monazite was conducted using the LA-ICPMS. All analyses were performed at the University of Tokyo.

The petrological and geochemical data showed that the granitic rock samples vary from monzogranite to granodiorite and exhibited a transition from I-type to S-type characteristics as the SiO_2 content increases, suggesting a crustal contamination or an input of magma derived from a more mature crustal source during the pluton fromation. The monazite grains in these samples yielded concordant $^{206}Pb/^{238}U$ ages (<10% discordant) of 68 ±0.3 Ma, except for a xenocrystic grain of ~425 Ma. The former age would reflect the timing of solidification, because some monazite grains retained oscillatory zoning. The monazite U-Pb age of ~68 Ma differs from the Rb-Sr whole-rock isochron age of 83 ±4 Ma (Shibata and Ishihara, 1979) and this difference suggests the Sr isotope variation caused by assimilation during the solidification. Furthermore, the $[^{143}Nd/^{144}Nd]_{68Ma}$ of analyzed monazite grains, including the xenocryst of ~425 Ma, ranges from 0.51225 ±0.00004 to 0.51208 ±0.00005 and most of them are identical within analytical uncertainty. It is suggested that the Nd isotope composition of granitic magma was homogeneous during the timing of monazite crystallization and might be inherited from its magma source. In contrast, the plagioclase grains in the same samples recorded the change in Sr isotope compositions. The Sr isotope compositions of plagioclase in a granodiorite sample showed a variation within a grain (e.g., core and rim of a single grain in a granodiorite sample yielded the $^{87}Sr/^{86}Sr$ of 0.7091 ±0.0003 and 0.7104 ±0.0001, respectively). Such intra-grain heterogeneity was not observed in a monzogranite having a higher SiO_2 content than the granodiorite sample. Assuming a series of differentiation of the magma forming both of monzogranite and granodiorite samples, a crustal contamination of crustal materials with radiogenic Sr into the granitic magma would have occurred when the composition of the magma was less differentiated. On the other hand, the identical Sr isotope compositions within the core and rim domains of plagioclase in the more differentiated samples can be explained by homogenization of magmas during the differentiation due to crystal fractionation. The isotopic homogenization accompanied by differentiation is also consistent with the uniform Nd isotope compositions of monazites in the monzogranite and granodiorite samples, because monazite generally crystallizes later than plagioclase (i.e., core domain). In conclusion, not only assimilation causing isotopic heterogeneity but also homogenization process played a significant role in the formation of the Busetsu granite pluton.

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