Solidification pressures and ages recorded in mafic microgranular enclaves in the Kurobegawa Granite

*Kota Suzuki[1], Tetsuo Kawakami[1], Shigeru Sueoka[2], Ayu Yamazaki[1], Saya Kagami[2], Tatsunori Yokoyama[2], Takahiro Tagami[1]

1. Department of Geology and Mineralogy, Graduate School of Science, Kyoto University, 2. Tono Geoscience Center, Japan Atomic Energy Agency

The Kurobegawa Granite is the youngest exposed pluton in the world and its exhumation mechanism is highly debated (e.g., Harayama, 2015; Ito et al., 2021). In reconstructing exhumation histories of young plutons, combining solidification pressure estimate by Al-in-hornblende geobarometers with age determination by U-Pb zircon dating is an effective method (Kawakami et al., 2021). In the case of the Kurobegawa pluton, however, rare hornblende occurrence in the host granite makes it difficult to estimate the solidification pressure by this method. Alternatively, we focus on mafic microgranular enclaves (MMEs) and evaluate whether the solidification pressures and ages of MMEs coincide with those of the host granite.

Two Kurobegawa granite samples with the MMEs, KRG19-A03 and -B08b, were collected from the middle and lower units of the pluton, respectively. Based on detailed petrographic studies, we identified appropriate amphibole and plagioclase domains coexisting with the required phases to apply the Al-in-hornblende geobarometer (Mutch et al., 2016) and the hornblende-plagioclase geothermometer (Holland & Blundy, 1994). Of the pressure-temperature (*P-T*) estimates obtained in this way, those plotted on the haplogranite solidus within uncertainty were taken as the solidification *P-T* conditions. In the case of KRG19-A03, the MME and the host granite yielded 1.8 ±0.3 to 2.4 ±0.4 kbar and 1.6 ±0.3 to 2.3 ±0.4 kbar, respectively. The MME and the host granite of KRG19-B08b respectively yielded 1.2 ±0.2 to 2.1 ± 0.3 kbar and 1.3 ±0.2 to 1.8 ±0.3 kbar. In each sample, the estimated solidification pressures of the MME and the host granite overlap well.

The common-Pb and initial disequilibria corrected weighted mean $^{206}Pb/^{238}U$ zircon ages following the methods of Sakata (2018) were calculated as 0.775 ±0.045 Ma (95% confidence level, hereafter) and 0.831 ±0.055 Ma for the MME and the host granite of KRG19-A03, respectively. The MME and the host granite of KRG19-B08b respectively yielded 0.672 ±0.033 Ma and 0.735 ±0.042 Ma. The ages for MMEs tend to be younger than the host granites, although they slightly overlap within uncertainty. In both lithologies, zircon occurs as matrix minerals and as inclusions in plagioclase rims. Meanwhile, in the host granites, zircon also occurs as early phases in plagioclase cores. Therefore, the age variations may reflect the difference in timing of zircon crystallization between the MMEs and the host granites. This is supported by the relatively lower zircon saturation temperatures of the MMEs (633-688 °C) compared to the lower Kurobegawa Granites (711-725 °C) (Ito et al., 2021). Therefore, the U-Pb zircon ages of the MMEs may better represent the final solidification timing of the host granites.

As discussed above, the MMEs record the same solidification pressures as the host granites and may better represent the timing of solidification of the pluton. Assuming rock density of 2700 kg/m^3 and lithostatic pressure, solidification depth of the MME from the middle unit (KRG19-A03) is estimated as 6.9 ±1.1 km to 9.2 ±1.5 km. Dividing the solidification depth by the U-Pb zircon age obtained from the same MME gives average exhumation rate of 7.1-14.5 mm/yr. Similarly, the MME from the lower unit (KRG19-B08b) gives average exhumation rate of 5.5-14.4 mm/yr. These exhumation rates are much larger than that of the ca. 5.6-5.2 Ma Shiaidani Granodiorite (0.93-2.5 mm/yr; Kawakami et al., 2021). Further petrological and geochronological studies using MMEs throughout the Kurobegawa pluton may help us to understand the exhumation mechanism of the world’s youngest exposed granitic pluton.

Acknowledgements
This study was funded by the Ministry of Economy, Trade and Industry (METI), Japan as part of its R&D supporting program titled “Establishment of Advanced Technology for Evaluating the Long-term Geosphere Stability on Geological Disposal Project of Radioactive Waste (Fiscal Years 2018 and 2021), Grunt Number JPJ007597”.

