Tectonic setting and heat source of an UHT metamorphic terrane constrained from prograde *P-T-t-melting* evolution

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The tectonic settings and heat sources of ultrahigh-temperature (UHT) metamorphic terranes are controversial. To understand their formation mechanisms, establishing prograde pressure-temperature-time-melting (*P-T-t-m*) evolutions are indispensable. However, the prograde information is not well understood due to the widespread chemical re-equilibrium under high-*T* conditions. In this study, a prograde *P-T-t-m* evolution of an UHT granulite from Rundvågshetta (Lützow-Holm Complex, East Antarctica) was established, by focusing on mineral and melt inclusions [nanogranitoids (NIs) and glassy inclusions (GIs)] enclosed in garnet and zircon.

Garnet in the UHT granulite consists of P-poor core, P-rich mantle and P-poor rim. By applying the Zr-in-rutile geothermometer [1] to rutile enclosed in garnet and by using the polymorphs of Al_2SiO_5 minerals enclosed in garnet as *P* indicators, the garnet core, mantle and rim were revealed to have grown during the prograde (840-920 °C/7.7-12.5 kbar), peak UHT (~ 1000 °C/14 kbar) and retrograde (~1000 °C/8 kbar and ~800 °C/5 kbar) stages, respectively. From the garnet core to mantle growth stages, pressure increase was confirmed (Result 1).

Zircon in the matrix shows five domains under cathodoluminescence (CL) images; inherited core, inner mantle, outer mantle, inner rim and outer rim. The inner mantle of zircon includes muscovite, quartz and NIs and yielded weighted mean U-Pb age of ~564 Ma. The inner rim is sector-zoned. Some matrix zircons have CL-bright inner rim, while others have CL-dark inner rim. The CL-bright and CL-dark inner rims of zircon yielded weighted mean ages of ~533 Ma and ~528 Ma, respectively. Zircon enclosed in the garnet core has the inner and outer mantles, suggesting that the inner mantle of zircon (~564 Ma) grew prior to the garnet core. Meanwhile, the CL-bright inner rim (~533 Ma) is developed in zircon enclosed in the garnet mantle. The array plot analysis showed that the CL-bright inner rim of zircon and the garnet mantle was in equilibrium at 950-1100 °C, suggesting the age of peak UHT metamorphism was ~533 Ma. Therefore, duration of prograde metamorphism from the muscovite + quartz stable stage to the peak UHT stage was estimated to be ~30 Myr (Result 2). Considering the previously-reported leucosome crystallization age of ~520 Ma [2], the duration of anatexis was constrained to be at least 40 Myr (Result 3).

Piston-cylinder remelting experiments were performed on NIs in zircon, and compositions of the GIs in garnet (GI_{Grt}) and the remelted GIs in zircon (GI_{Zrn}) were determined. In the CIPW normative Qz-Ab-Or diagram, the GI_{Grt} plot closer to the Qz-Or axis than the GI_{Zrn}. The GI_{Zrn} plots approximately on the Qz-Or cotectic line for 5 kbar, while the GI_{Grt} plots approximately on the Qz-Or cotectic line for 10 kbar and also on the tie line between Qz and previously-reported whole-rock composition of the UHT granulite from Rundvågshetta [3]. The GI_{Grt} enclosed in the outer part of the garnet core plots closer to the whole rock composition. Also, rutile enclosed in the outer part of the garnet core shows higher Zr contents, suggesting the temperature increase during the garnet core growth. The systematic compositional change of GI_{Zrn} and GI_{Grt} can be interpreted as indicating the change of melt composition towards the higher *P-T* condition maintaining chemical equilibrium from the zircon inner mantle growth stage (~ 700-800 °C) to the garnet core growth stage (840-920 °C/7.7-12.5 kbar). Therefore, the temperature increase during the prograde metamorphism was probably slow enough to maintain the chemical equilibrium between melt and bulk residue (Result 4).

All the above results 1-4 indicate that the UHT metamorphism in Rundvågshetta can be explained by a process in which the radiogenic self-heating leads the thickened crust to the UHT condition during the continental-collision [4].

[1] Tomkins+ 2007 JMG [2] Fraser+ 2000 JMG [3] Durgalakshmi+ 2021 J. Pet [4] Clark+ 2011 Elements

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