東南極リュツォ・ホルム岩体の天文台岩に産出するグラニュライトについての岩石学的解析とジルコンのウラン−鉛年代及び希土類元素組成

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Petrological analyses and U-Pb geochronology with REE geochemistry of zircons in granulites from Tenmondai Rock in the Lützow-Holm Complex, East Antarctica

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The Lützow-Holm Complex (LHC) of East Antarctica is regarded as one of the high-grade metamorphic terranes formed through collisional orogeny during late Neoproterozoic-Cambrian Gondwana amalgamation. Although previous studies suggested that metamorphic grade systematically increases from the northeastern part (amphibolite facies) to the southwestern part (granulite facies) of the complex (e.g., Hiroi et al., 1991), some recent studies have proposed that it can be subdivided into three crustal units based on structural, geochemical and geochronological evidences, particularly protolith ages; Neoarchean (ca. 2.5 Ga) block (Shirase microcontinent) in the south, Neoproterozoic (ca. 1.0 Ga) volcanic arcs in the north, and a suture zone with Paleoproterozoic (ca. 1.8 Ga) fragments in the central part of the LHC (e.g., Tsunogae et al., 2014, 2015, 2016; Takahashi et al., 2018; Takamura et al., 2018). All the three units are traditionally thought to have been undergone high-grade metamorphism at ca. 550-530 Ma.

Recently, the timing and conditions of each metamorphic stage in the LHC have been estimated based on U-Pb geochronology of zircon and monazite, and trace element geochemistry of zircon, monazite and other metamorphic minerals such as garnet. For example, U-Pb-Th dating of zircon and monazite combined with trace element geochemistry of zircon, monazite, and garnet from Skallen and Skallevikshalsen in the granulite-facies region of the LHC yielded older (~650-580 Ma) and younger (~560-500 Ma) metamorphic age populations as evidences of polymetamorphism (Hokada and Motoyoshi, 2006; Kawakami et al., 2016). However, detailed petrological and geochronological studies in the amphibolite-facies region and the amphibolite-granulite transition zone in the northeastern part of LHC are still limited.

Tenmondai Rock area is one of exposures in the amphibolite-granulite transition zone, and dominantly composed of garnet-biotite gneisses and migmatites with layers of garnet-biotite gneisses and amphibolites. Some previous studies reported limited petrological and geochronological data from this region such as the peak *P-T* conditions of about 750°C and 7.2-7.5 kbar (Hiroi et al., 1983) and zircon U-Pb age of 580±7 and 540±7 Ma (Dunkley et al., 2014). In this study, we performed detailed petrological and geochronological investigations of metabasite and pelitic gneiss from this region to unravel *P-T-t* evolution of the amphibolite-granulite transition zone of the LHC.

A metabasite sample is dominantly composed of garnet, orthopyroxene, plagioclase, quartz and biotite. Skeletal garnet shows some grossular-rich portions with quartz, plagioclase, apatite and crystallized melt inclusions suggesting crystallization in melt-existing condition. Orthopyroxene + plagioclase symplectite surrounding garnet also suggests isothermal-decompression probably along a clockwise *P-T* path. On the other hand, garnet-biotite-sillimanite gneiss (metasediment), which comprises garnet, plagioclase, quartz, K-feldspar, biotite and sillimanite, contains intercalated kyanite-bearing quartzo-feldspathic leucosome possibly formed by prograde partial melting.

The results of phase equilibrium modelling in the system NCKFMASHTO for a metabasite show the peak assemblage (garnet + orthopyroxene + plagioclase + ilmenite + quartz + K-feldspar and melt) is stable at *P-T* ranges of 800-900°C and 4-9 kbar. Similar *P-T* ranges (805-847°C at 8 kbar, and 6.5-9.25 kbar at 800°C) were also obtained from the same metabasite sample using garnet-orthopyroxene geothermometry and garnet-orthopyroxene-plagioclase-quartz geobarometry. Thus, the rocks in Tenmondai Rock area are estimated to have reached granulite-facies condition during high-grade metamorphism.

U-Pb dating for metamorphic zircons in a metabasite sample by LA-ICP-MS yielded late Neoproterozoic to Cambrian ages (ca. 550-500 Ma), whereas those in pelitic gneiss and leucosome samples show slightly older ages (ca. 650-550 Ma). These data may suggest that the partial melting and formation of leucosome might have occurred at ca. 650-550 Ma before crystallization of metamorphic zircon in metabasite. We also evaluated rare earth elements (REEs) in metamorphic zircons and their ages, and confirmed that the normalized Lu/Gd values are enriched and Eu/Eu* ($=Eu_N/(Sm_N \times Gd_N)^{1/2}$) values are depleted for zircons younger than ca. 540 Ma. These features hypothetically suggest breakdown of garnet and formation of plagioclase + orthopyroxene symplectite during isothermal decompression at ca. 540 Ma.

The timing of prograde partial melting (ca. 650-550 Ma) and isothermal-decompression (after ca. 540 Ma) in Tenmondai Rock is roughly similar with ages of prograde (~650-580 Ma) and peak (~560-500 Ma) metamorphism in the granulite-facies region of the LHC (Hokada and Motoyoshi, 2006; Kawakami et al., 2016). Thus, the northeastern and southwestern parts of the LHC might have experienced similar heating-compression and exhumation processes during Gondwana amalgamation.

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