Metamorphic condition and age of a pelitic gneiss from Niban-nishi Rock of Niban Rock in the Lützow-Holm Complex, East Antarctica

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The Lützow-Holm Complex (LHC) in eastern Dronning Maud Land, East Antarctica is a Neoproterozoic-Cambrian high-grade metamorphic complex extending for about 500 km along Prince Olav Coast and Soya Coast. The LHC has been characterized by continuous increase in metamorphic grade from northeast to southwest (Hiroi et al., 1991) and metamorphic age of 600–520 Ma (Dunkley et al., 2020 and reference therein). The LHC is divided into three metamorphic zones referred to as the amphibolite-facies zone, transitional zone, and granulite-facies zone from northeast to southwest (Hiroi et al., 1991). Cape Hinode located in the amphibolite-facies zone is known as that the exposure shows different features from other exposures in the LHC such as Tonian metamorphic age of 1017–960 Ma, granulite-facies metamorphic rocks, and tonalite dominant lithology (Yanai and Ishikawa, 1978; Shiraishi et al., 1994; Hiroi et al., 2006, 2008; Dunkley et al., 2014). Recently, Baba et al. (2021) revealed that Akebono Rock, an exposure located about 12 km northeast of Cape Hinode in the amphibolite-facies zone, records Tonian metamorphism of 977–917 Ma. Baba et al. (2021) reported that garnet preserves prograde zoning and kyanite is stable in the matrix in Akebono Rock. Niban rock is a 2.5 km x 3.5 km exposure located in amphibolite-facies zone of the LHC and located at about 15 km to the southwest of Cape Hinode. Niban Rock is underlain mainly by sillimanite-garnet-biotite gneiss, biotite gneiss, and biotite-hornblende gneiss with minor metabasite, calc-silicate gneiss, granite, and aplite (Kizaki et al., 1983). In Niban Rock, Dunkley et al. (2014) conducted zircon U–Pb dating and monazite U–Th–Pb dating and reported 551 Ma as magmatic age and 532 Ma as metamorphic age from metagranitic dyke and 940 Ma as protolith age from augen granitic orthogneiss. Kitano et al. (2021) reported zircon U–Pb age of 998 Ma as metamorphic age from Niban Rock. However, comprehensive analysis of metamorphism including detailed textural observation, mineral chemistry, whole-rock chemistry, P–T condition, and age was not performed at Niban Rock yet. In this study, we describe a garnet-bearing migmatitic pelitic gneiss collected from Niban-nishi Rock of Niban Rock in the LHC. We estimated the P–T condition of retrograde stage based on garnet–biotite geothermometer and garnet–sillimanite–quartz–plagioclase geobarometer. Phase equilibrium modeling was applied to determine the minimum temperature required for partial melting and constrain peak metamorphic temperature. Monazite electron microprobe U–Th–Pb dating was also performed, and we revealed that the gneiss was suffered from Tonian metamorphism.

The studied pelitic gneiss (sample no. TM11020804A) was collected from Niban-nishi Rock in Niban Rock during the 52nd Japanese Antarctic Research Expedition (JARE 52). The gneiss is composed mainly of quartz, plagioclase, biotite, sillimanite, K-feldspar, muscovite, garnet with minor amounts of zircon, monazite, apatite, and ilmenite. The gneiss shows foliation defined by shape-preferred orientations of sillimanite, biotite, muscovite, and quartz. Monazite occurs in the matrix and as inclusion in biotite or garnet (up to 0.1 mm long). Compositional zoning in garnet shows outward decrease in Xalm and increase in Xsps, which is regarded as retrograde zoning. Garnet–biotite geothermometer of Holdaway (2000) and garnet–sillimanite–quartz–plagioclase geobarometer of Holdaway (2001) were used for the estimation of retrograde condition. We used the compositions of rims of matrix garnet, biotite, and plagioclase and obtained 620–670 °C and 0.42–0.60 GPa as the retrograde condition of regional metamorphism. We also performed phase equilibrium modeling based on the result of whole-rock chemical analysis using a free energy minimization software Perple_X (Connolly, 2005, 2009) to obtain stable mineral assemblages in each P–T condition. Based on detailed textural observation, we consider that the most plausible mineral assemblage at peak metamorphism was garnet + biotite + melt + ilmenite + plagioclase + K-feldspar + sillimanite + quartz. According to the P–T pseudosection, the assemblage is stable under 690–830 °C and 0.35–0.80 GPa, and thus we consider that the peak metamorphic temperature was lower than ~830 °C. Monazite electron microprobe U–Th–Pb dating has an advantage that we can clarify the occurrence of analyzed monazite. As a result, we obtained the weighted mean age of 940.1 ± 9.8 Ma (MSWD = 0.31, 2σ level) from the 62 ages of 1015–889 Ma. We regarded that there is no relation between the occurrence of monazite and the obtained ages. Based on detailed textural observation, the age obtained in this study corresponds to the timing of metamorphism from prograde to retrograde stages. The metamorphic age is consistent with the neighboring exposures of Cape Hinode and Akebono Rock, but the metamorphic grade is lower than Cape Hinode and compositional zonation of garnet and stable phase of alminosilicate are different from Akebono Rock.

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