Metamorphic conditions of garnet-bearing gneisses from Niban Rock in the Lützow-Holm Complex, East Antarctica

Yuki Mori[1], Takeshi Ikeda[2], and Tomoharu Miyamoto[2]
[1]*Department of Earth and Planetary Sciences, Graduate School of Science, Kyushu University*
[2]*Department of Earth and Planetary Sciences, Faculty of Science, Kyushu University*

The metamorphic grade of the Lützow-Holm Complex (LHC) had been considered to be showing progressive increase from the upper amphibolite facies to granulite facies toward the southwest of the complex. Based on the presence or absence of Ca-poor amphiboles and orthopyroxene, the LHC is divided into three metamorphic zones referred to as the amphibolite-facies zone, transitional zone, and granulite-facies zone (Hiroi et al., 1991). The LHC is considered to have experienced a clockwise pressure-temperature (*P-T*) path because kyanite is found as inclusion in garnet from throughout the complex, and sillimanite is a stable phase in present matrix (e.g., Hiroi et al., 1991). In the amphibolite-facies zone, Cape Hinode shows obviously higher metamorphic grade corresponding to granulite facies and is considered to allochthonous block (Hiroi et al., 2006). Recently, Suzuki et al. (2019, JpGU) reported that the metamorphic condition of Akarui Point located in the transitional zone attained 850 °C in kyanite stability field using Zr-in-rutile geothermometer for pelitic gneiss. Therefore, reexamination of the metamorphic conditions of the LHC is required.

In this study, we investigated the chemical compositions of minerals of both pelitic and mafic gneisses from Niban Rock and estimated their *P-T* conditions. Niban rock is a 2.5 km x 3.5 km exposure located in amphibolite-facies zone of the LHC. It is 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). The studied samples were collected during JARE 52.

Pelitic gneiss

The constituent minerals of studied pelitic gneiss (sample no. TM11020702A) are quartz, garnet, biotite, sillimanite, plagioclase, ilmenite, kyanite, zircon, rutile, and monazite. Kyanite in the matrix is rimmed by plagioclase and is not in contact with quartz directly. Sillimanite is abundant as aluminosilicate in the matrix rather than kyanite. Rutile occurs only as inclusion in garnet with or without ilmenite. Ilmenite occurs both in the matrix and as inclusion in garnet. Zircon occurs in the matrix and as inclusion in garnet, plagioclase, and quartz. Quartz, kyanite, and rutile are directly in contact with each other in the core of garnet. Applying Zr-in-rutile geothermometer of Tomkins et al. (2007) to the rutile without ilmenite in garnet core yielded 632 – 689 °C, assuming pressure of 6 – 14 kbar. This temperature is considered as that at start of garnet formation in the kyanite stability field. Garnet shows monotonic decrease in X_{Mg} from core to rim, which is regarded as retrograde zoning. Anorthite content of plagioclase is almost homogeneous in one grain except at the rim, where it slightly increases. We applied garnet-biotite geothemometer of Holdaway (2000) and garnet-sillimanite-quartz-plagioclase geobarometer of Holdaway (2001) for the estimation of retrograde conditions. The condition of the retrograde stage can be estimated using pairs of maximum and minimum X_{Mg} of matrix biotite, and rim of garnet, and rim of plagioclase with high anorthite content, and we obtained 654 – 687 °C and 4.5 – 5.2 kbar as the condition. In the *P-T* pseudosection calculated in the K_2O-Na_2O-CaO-MgO-MnO-FeO-Al_2O_3-TiO_2-SiO_2-H_2O system, the stability field of the matrix assemblage garnet + biotite + quartz + sillimanite + plagioclase + ilmenite appears on the *P-T* field of 625 – 720 °C and 4.2 – 7.4 kbar, which is considered to be peak metamorphic condition.

Mafic gneiss

The constituent minerals of studied mafic gneiss (sample no. TM11020803A) are garnet, hornblende, quartz, plagioclase, biotite, and ilmenite. Garnet in the gneiss does not have corona and directly contacts to hornblende, biotite, quartz, or plagioclase. Garnet has almost homogeneous composition. Plagioclase has lower anorthite content core and higher anorthite content rim. X_{Mg} of hornblende slightly decreases from core to rim. Hornblende has variation in chemical composition which can be explained by tschermak substitution. The condition of the retrograde was estimated using rim compositions of garnet, hornblende, and plagioclase, and we obtained 491 – 589 °C and 6.7 – 7.8 kbar applying garnet-hornblende geothermometers of Powell (1985) and Ravna (2000) and garnet-hornblende-plagioclase-quartz geobarometer of Kohn and Spear (1990) as the condition.

Discussion & Conclusion

We obtained prograde temperature of 632 – 689 °C in kyanite stability field, peak temperature of 625 – 720 °C (at 4.2 – 7.4 kbar), and retrograde temperature of 654 – 687 °C (at 4.5 – 5.2 kbar) using pelitic gneiss from Niban Rock. These temperatures are notably lower than the metamorphic condition of Akarui Point reported by Suzuki et al. (2019, JpGU). The *P*-*T* path inferred from our results is clockwise, which is same as other exposures in the LHC. In Akebono Rock located 12 km to the northeast of Cape Hinode, Baba et al. (2019, GSJ) estimated the peak metamorphic conditions as 650 – 700 °C and 8 ± 1 kbar using pelitic gneiss and 650 – 750 °C and 8 ± 0.5 kbar using garnet amphibolite. Therefore, we consider that the metamorphic conditions of amphibolite-facies zone would not attain granulite facies unlike transitional zone.

References

Baba, S., Hokada, T., Kamei, A., Kitano, I., Motoyoshi, Y., Metamorphic conditions of pelitic gneisses in Prince Olav Coast, East Antarctica. 126th GSJ Annual Meeting Abstract, 2019.

Ferry, J.M., Watson, E.B., New thermodynamic models and revised calibrations for the Ti-in-zircon and Zr-in-rutile thermometers. Contributions to Mineralogy and Petrology, 154, 429-437, 2007.

Hiroi, Y., Motoyoshi, Y., Satish-Kumar, M., Kagashima, S., Suda, Y., Ishikawa, N., Granulites from Cape Hinode in the amphibolite-facies eastern part of Prince Olav Coast, East Antarctica: New evidence for allochthonous block in the Lützow-Holm Complex. Polar Geoscience, 19, 89-108, 2006.

Hiroi, Y., Shiraishi, K., Motoyoshi, Y., Late Proterozoic paired metamorphic complexes in East Antarctica, with special reference to the tectonic significance of ultramafic rocks. In Geological Evolution of Antarctica (Thomson, M.R.A, Crame, J.A. and Thomson, J.W. Eds.), Cambridge University Press, Cambridge, 83-87, 1991.

Holdaway, M.J., Application of new experimental and garnet Margules data to the garnet-biotite geothermometer. American Mineralogist, 85, 881-892, 2000.

Holdaway, M.J., Recalibration of the GASP geobarometer in light of recent garnet and plagioclase activity models and versions of the garnet–biotite geothermometer. American Mineralogist, 86, 1117-1129, 2001.

Kizaki, K., Hiroi, Y., Kanisawa, S., Explanatory text of geological map of Niban Rock, Antarctica. Antarctic Geological Map Series, Sheet 17 Niban Rock. NIPR, Tokyo, 1983.

Kohn, M.J., Spear, F.S., Two new geobarometers for garnet amphibolites, with applications to southeastern Vermont. American Mineralogist, 75, 89-96, 1990.

Powell, R., Regression diagnostics and robust regression in geothermometer/geobarometer calibration: the garnet - clinopyroxene geothermometer revisited. Journal of Metamorphic Geology, 3, 231-243, 1985.

Ravna, E.K., Distribution of Fe^{2+} and Mg between coexisting garnet and hornblende in synthetic and natural systems: An empirical calibration of the garnet-hornblende Fe-Mg geothermometer. Lithos, 53, 265-277, 2000.

Suzuki, K., Kawakami, T., Igami, Y., Pressure-temperature estimates of the Lützow-Holm Complex utilizing distributions of trace elements and inclusions in garnet porphyroblasts in pelitic gneisses. JpGU Meeting 2019 Abstract, 2019.

Tomkins, H.S., Powell, R., Ellis, D.J., The pressure dependence of the zirconium-in-rutile thermometer. Journal of Metamorphic Geology, 25, 703-713, 2007.