Polar Geosci., 19, 109–117, 2006

Rb-Sr and Sm-Nd mineral isochron ages of a pegmatitic gneiss from Oku-iwa Rock, Lützow-Holm Complex, East Antarctica

Yoshinobu Kawano[1]*, Naoko Nishi[2] and Hiroo Kagami[3]

[1]*Center for Research and Development of Higher Education, Saga University, Honjo 1, Saga 840-8502*
[2]*Yamaga City, Yamagata 990-8560*
[3]*Graduate School of Science and Technology, Niigata University, 8050, Ikarashi-2, Niigata 950-2181*
**Corresponding author. E-mail: kawanoy@cc.saga-u.ac.jp*

(Received March 20, 2006; Accepted July 20, 2006)

Abstract: Oku-iwa Rock is located in the transitional zone between granulite- and amphibolite-facies metamorphic zones in the Lützow-Holm Complex (LHC), East Antarctica. Hornblende biotite (HB) gneiss widely outcrops in the northern part of this area. Sm-Nd and Rb-Sr mineral isochron ages obtained from pegmatitic HB gneiss are 578±36 Ma and 431±14 Ma with initial isotopic ratios of 0.511892±0.000040 and 0.70718±0.00038, respectively. The former mineral isochron age is consistent with the Rb-Sr whole rock isochron age of the HB gneiss (583 Ma). The latter age is close to the previously published Rb-Sr mineral isochron age of granitic rocks (418 Ma) in Oku-iwa Rock, implying that these ages represent the time when the rocks cooled down to the closure temperature of biotite. The granodioritic precursor formed at 674 Ma was gradually cooled down and its temperature reached 700℃ at 583 Ma based on a previous report. Temperature of the HB gneiss rose at 578 Ma by injection of source material for the pegmatitic HB gneiss and rose again at 529 Ma (SHRIMP U-Pb zircon age) by regional metamorphism. At 485 Ma, the temperature of the gneisses rose for the third time by intrusion of granitic rocks. After the intrusion, the constituent rocks of Oku-iwa Rock gradually cooled by uplifting and the temperature reached 310℃ at 431 Ma.

key words: Rb-Sr and Sm-Nd geochronology, hornblende biotite gneiss, Oku-iwa Rock, Lützow-Holm Complex

1. Introduction

Oku-iwa Rock is located 58 km northeast of Syowa Station, East Ongul Island, and is exposed, in the transitional zone between the granulite-facies and amphibolite-facies metamorphic zones defined by Hiroi *et al.* (1983). Nishi *et al.* (2002) reported Rb-Sr and Sm-Nd whole rock isochron ages of hornblende biotite gneiss in Oku-iwa Rock, and discussed the thermochronological sequence of the area. According to this sequence, the precursor of hornblende biotite gneiss (abbreviated to HB gneiss hereafter) was igneous rock with granodioritic compositions generated at 674±22 Ma defined by the Sm-Nd whole rock isochron method. The second stage, defined by the Rb-Sr whole rock isochron age of 583±56 Ma can be interpreted in either of two ways: (1) the temperature of granodioritic rocks formed at *ca*. 670 Ma continued as the high temperature until 583 Ma, or (2) re-fusion of granodioritic rocks formed at 674 Ma took place at 583 Ma. After 480 Ma, which is the Rb-Sr whole rock isochron age of granitic rock in this area, the constituent rocks of Oku-iwa Rock cooled by uplifting (Nishi *et al*., 2002). Nishi *et al*. (2002) proposed two interpretations for the age difference between the two whole rock isochron ages of the hornblende biotite gneiss, and emphasized that further examination of the two ages is necessary in the future. In this paper, we report the Rb-Sr and Sm-Nd mineral isochron ages for a rock sample drawn from the hornblende biotite gneiss described by Nishi *et al*. (2002) to shed additional light on the thermal history of Oku-iwa Rock.

2. Analyzed samples

Oku-iwa Rock on the Prince Olav Coast is located in the transitional zone in the LHC (Hiroi *et al*., 1983). It is composed dominantly of leucocratic biotite gneiss, migmatitic biotite hornblende gneiss, hornblende biotite gneiss, pink granite, aplite and pegmatite (Fig. 1). The gneissose rocks have a foliation with general trend striking E-W and dipping 50–80°S (Nakai *et al*., 1981). The HB gneiss is the lowermost member, which widely outcrops in the northern part of the area. The granite associated with aplite and pegmatite intrudes into the HB gneiss as two discordant masses and small scale dykes on the northern seashore of Oku-iwa Rock (Nishi *et al*., 2002). The pegmatite (coarse-grained granite named in Nishi *et al*., 2002) is characterized by reddish potassium feldspar megacryst and voluminous magnetite. Some vertical pegmatitic dykes striking NE-SW and ranging in width from 50 cm to 2 m cut pink granite at the seashore.

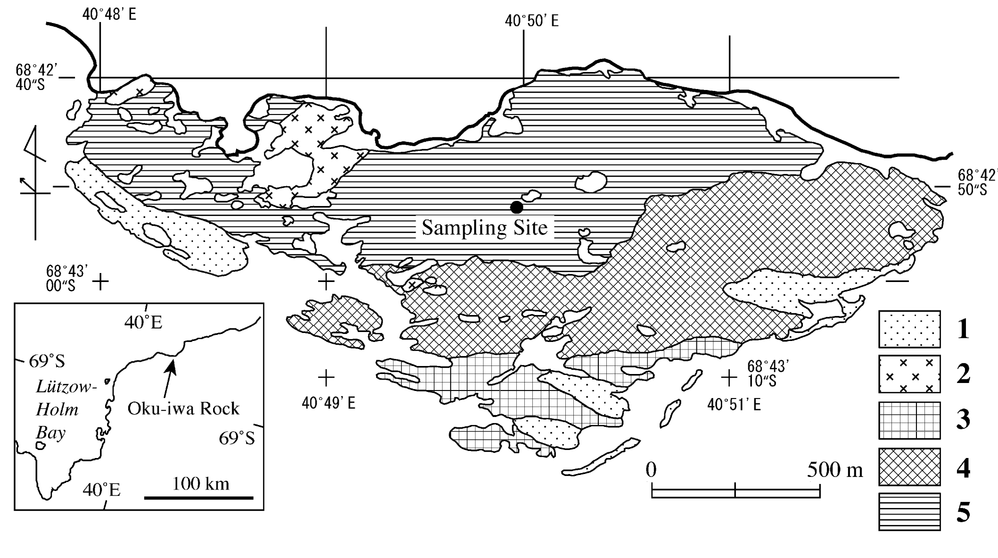

Fig. 1. Geological map of Oku-iwa Rock (simplified from Nakai et al., 1981). 1, Moraine; 2, Granite; 3, Leucocratic biotite gneiss; 4, Migmatitic biotite hornblende gneiss; 5, hornblende biotite gneiss.

Nishi *et al*. (2002) collected ten samples of HB gneiss from a single outcrop for elucidation of the closure system in Rb-Sr and Sm-Nd isotopic geochronology. Eight samples were collected within about 1 m, and two other samples were taken from outcrops 5 m and 15 m away (Fig. 2). They consist of quartz, K-feldspar, plagioclase, biotite and hornblende with magnetite and ilmenite as accessory minerals. The gneiss was formed from igneous rocks with granodioritic chemical compositions and/or volcanogeneous sedimentary rocks with similar chemical compositions (Nishi *et al*., 2002). A reliable Rb-Sr whole rock isochron was not defined using ten HB gneiss rocks, because of scatter of the isotopic data. Nishi *et al*. (2002) examined sampling positions and rock facies, and excluded three pegmatitic HB gneisses (Sp. Nos. 18, 21 and 23) from the age calculation. The pegmatitic HB gneisses were thought to derive from different sources from other HB gneissose rock samples, because they are too coarse-grained rocks (Nishi *et al*., 2002). Especially, specimen No. 18 shows lower K_2O, Ba and Rb contents in comparison with two other pegmatitic HB gneisses, and plots above the Rb-Sr whole rock isochron. Thus, the authors calculated an Rb-Sr whole rock isochron age of 583 ± 56 Ma using seven samples (Sp. Nos. 14, 15–17, 19, 20 and 22). Moreover, six of them (Sp. Nos. 15–17, 19, 20 and 22) define an Sm-Nd whole rock isochron with an age of 674 ± 22 Ma.

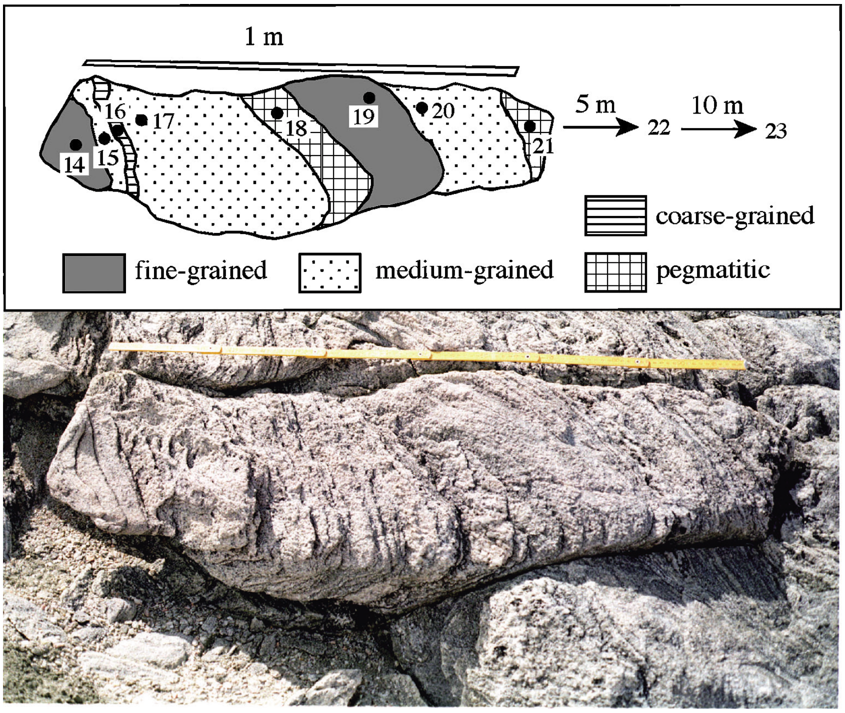

Fig. 2. Outcrop of hornblende biotite gneiss and analyzed samples (Nishi et al., 2002). Nos. 14 and 19, fine-grained hornblende biotite gneiss; Nos. 15, 17, 20 and 22, medium-grained hornblend biotite gneiss; Nos. 16, coarse-grained hornblende biotite gneiss; Nos. 18, 21 and 23, pegmatitic hornblende biotite gneiss.

A pegmatitic HB gneiss (No. 21), described by Nishi *et al*. (2002), is selected for Rb-Sr and Sm-Nd mineral isotopic analysis to elucidate the relation between the pegmatitic HB gneiss and surrounding fine- to coarse-grained HB gneiss. Unfortunately, there is not enough for mineral isotopic analysis of the other two pegmatitic HB gneisses. The rock contains slightly more quartz, biotite and hornblende and less potassium feldspar than other pegmatitic HB gneisses. And it shows foliations, which are concordant with the gneissose structure of the surrounding HB gneiss. Based on the examination method of Osanai *et al*. (1992), DF3 and DF4 values of the pegmatitic HB gneiss are slightly negative, implying that the protolith for the rock was sedimentary rock (Nishi *et al*., 2002). However, the rock is plotted in the basalt-andesite field in the ACF diagram (Fig. 5–7 on page 45, Winkler, 1979) (Nishi *et al*., 2002), and has metaluminous chemical composition, having an aluminum saturation index of 0.93. Therefore, the pegmatitic HB gneiss may have originated from igneous rocks and been affected by metamorphism after injection.

3. Analytical procedures

Hornblende, biotite and felsic fractions were separated from a rock specimen by hydraulic elutriation, isodynamic separation and hand picking. Isotope analyses were performed with MAT 261-type (modified from MAT 260) and MAT 262-type mass spectrometers at Niigata University. Extraction procedures for Rb, Sr, Sm and Nd followed Kawano *et al*. (1999). Ratios of $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$ were normalized to $^{86}Sr/^{88}Sr=0.1194$ and $^{146}Nd/^{144}Nd=0.7219$, respectively. The average $^{87}Sr/^{86}Sr$ ratio of NBS987 during this study was 0.710216 ± 0.000014 ($n=13$). The $^{87}Sr/^{86}Sr$ ratios in Table 1 were reported relative to NBS987=0.710218 (Nishi *et al*., 1999). $^{143}Nd/^{144}Nd$ ratios in Table 1 were reported relative to 0.512115 (JNdi-1, Geological Survey of Japan standard) corresponding to 0.511858 of LaJolla (Tanaka *et al*., 2000). The blanks for the procedures were <0.14 ng of Rb, <0.99 ng of Sr, <0.03 ng of Sm and <0.26 ng of Nd. The age and initial $^{87}Sr/^{86}Sr$ ratio were calculated by the computer program of Kawano (1994) using the equation of York (1966) with the following decay constants: $\lambda\ ^{87}Rb=1.42\times10^{-11}/y$ (Steiger and Jäger, 1977) and $\lambda\ ^{147}Sm=6.54\times10^{-12}/y$ (Lugmair and Marti, 1978). Estimated precisions in the age calculation of $^{87}Rb/^{86}Sr$ and $^{87}Sr/^{86}Sr$ ratios are 1% and 0.015%, respectively. Likewise, those of $^{147}Sm/^{144}Nd$ and $^{143}Nd/^{144}Nd$ ratios are 0.1% and 0.015%, respectively.

Table 1. Rb, Sr, Sm and Nd concentrations and $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$ isotopic ratios of pegmatitic HB gneiss.

Sample	Rb (ppm)	Sr (ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$ (2σ)	Sm (ppm)	Nd (ppm)	$^{147}Sm/^{144}Nd$	$^{143}Nd/^{144}Nd$ (2σ)
Whole rock	78.4	208	1.091	0.71368(1)	6.42	24.9	0.1560	0.512482(14)
Felsic fraction	5.39	305	0.051	0.70757(1)	7.12	25.2	0.1709	0.512544(14)
Hornblende	63.8	23.9	7.748	0.75580(1)	26.0	84.0	0.1874	0.512599(15)
Biotite	373	5.74	211.4	1.98409(1)	2.18	8.48	0.1553	0.512479(12)

4. Results and discussion

4.1. Rb-Sr and Sm-Nd mineral isochron ages of pegmatitic HB gneiss

The analytical results are listed in Table 1. The mineral isochron plots for pegmatitic HB gneiss are shown in Figs. 3 and 4. In the Rb-Sr system, biotite, hornblende, felsic fraction and whole rock points define an isochron age of 431±14 Ma with an initial Sr isotopic ratio of 0.70718±0.00038 (Fig. 3). The mineral isochron age is controlled by the $^{87}Sr/^{86}Sr$ and $^{87}Rb/^{86}Sr$ ratios of biotite, whose closure temperature is 310 ±40°C (Nishimura and Mogi, 1986). The age is close to previously published Rb-Sr mineral isochron age of granitic rocks in Oku-iwa Rock (418±2 Ma; Nishi *et al.*, 1999), implying that these ages represent when the rocks cooled down to the closure temperature of biotite. The obtained initial Sr isotopic ratio is higher than that of the whole rock isochron (0.70556; Nishi *et al.*, 2002) for HB gneiss, suggesting that the source material for the pegmatitic HB gneisses is different from that for surrounding HB gneiss.

Sm-Nd isotopic ratios of biotite, hornblende, felsic fraction and whole rock define

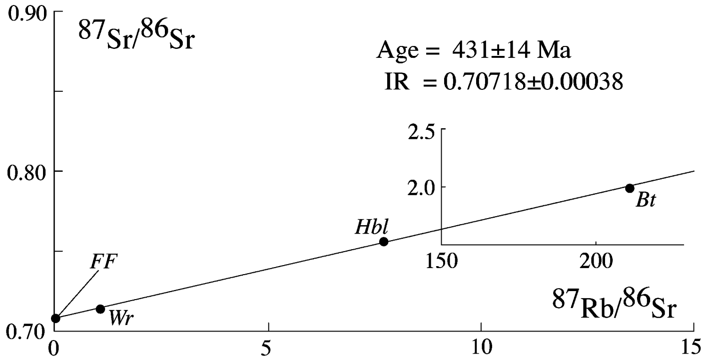

Fig. 3. Rb-Sr mineral isochron diagram of pegmatitic HB gneiss. Wr, whole rock; Hbl, hornblende; Bt, biotite; FF, felsic fraction; IR; initial $^{87}Sr/^{86}Sr$ ratio.

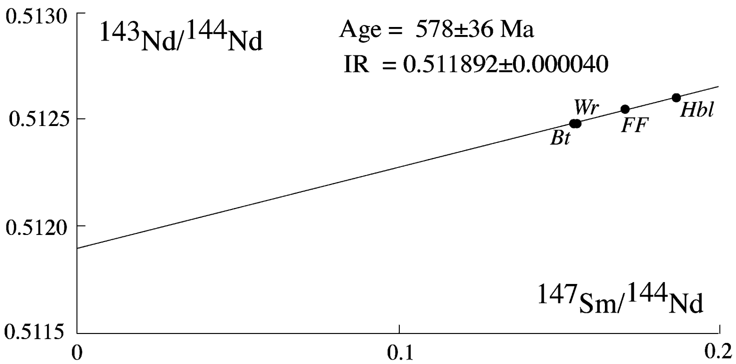

Fig. 4. Sm-Nd mineral isochron diagram of pegmatitic HB gneiss. Wr, whole rock; Hbl, hornblende; Bt, biotite; FF, felsic fraction; IR; initial $^{143}Nd/^{144}Nd$ ratio.

an isochron age of 578±36 Ma with an initial Nd isotopic ratio of 0.511892±0.000040. This age is consistent with the Rb-Sr whole rock isochron age of 583±56 Ma (Nishi *et al*., 2002). Closure temperature of Sm-Nd age using hornblende is estimated to be 738 ±60°C (Burton and O'Nions, 1990). Furthermore, Goldberg and Dallmeyer (1997) pointed out that the Sm-Nd age using hornblende for mylonitic amphibolite indicates the time of crystallization before mylonitic deformation. Additionally, Kamei *et al*. (2000) also concluded that the Sm-Nd internal isochron, using hornblende, felsic fraction and whole rock, may be close to the crystallization age of plutonic rocks. Accordingly, the Sm-Nd internal isochron age in this study is thought to express the crystallization age of the pegmatitic HB gneiss. The obtained initial Nd isotopic ratio is slightly lower than that of the whole rock isochron (0.511921; Nishi *et al*., 2002). Moreover, the initial Sr isotopic ratio corrected by the crystallization age of 578 Ma for the pegmatitic HB gneiss (SrI_{578Ma}=0.70469) is different from those of the HB gneiss (SrI_{578Ma}=0.70542–0.70593). Based on combined initial Sr and Nd isotopic ratios, the pegmatitic HB gneiss may have originated from a different source of the HB gneiss. As mentioned above, Nishi *et al*. (2002) have already pointed out that the pegmatitic HB gneiss has a different origin from the HB gneiss based on the grain size of rocks and whole rock isotopic ratios. The result from this study supports discussion of Nishi *et al*. (2002).

4.2. Cooling history of Oku-iwa Rock

Amphibolite- to granulite-facies metamorphic rocks in the LHC indicate U-Pb zircon and CHIME monazite ages of 520–560 Ma (Shiraishi *et al*., 1994, 2003; Asami *et al*., 1997). These ages have been interpreted as the times of peak metamorphism in the Complex. On one side, igneous and metamorphic rocks in the LHC having older Rb-Sr whole rock isochron ages than the U-Pb zircon ages have been reported by many authors (Shibata *et al*., 1986; Shimura *et al*., 1998; Nishi *et al*., 2002; Kawano *et al*., 2005). Dickin (1995) and Kagami *et al*. (2003) noted that it seems to be difficult to attain regional Sr homogenization without activity of magma or fluid, even under metamorphism at a lower crustal level. This suggests that the Rb-Sr whole rock isochron age for metamorphosed rocks should be interpreted as the time of geological events before the metamorphism. The Rb-Sr whole rock isochron age of the HB gneiss (583±56 Ma) coincides with the Sm-Nd mineral isochron age of the pegmatitic HB gneiss (578±36 Ma) within error ranges. However, 578 million years before, the Sr isotopic ratio for the HB gneiss (SrI_{578Ma}=0.70542–0.70593) was different from that of the pegmatitic HB gneiss (SrI_{578Ma}=0.70469). Therefore, the Rb-Sr isotopic system for the HB gneiss could not have attained isotopic homogenization by injection of original melt of the pegmatitic HB gneisses. As mentioned above, the pegmatitic HB gneisses have undergone regional metamorphism based on their gneissose structure (Nishi *et al*., 2002). This fact suggests that metamorphism in the transitional zone took place after 578 Ma. Unfortunately, no U-Pb zircon or CHIME monazite ages are obtained from Oku-iwa Rock, however, the U-Pb zircon age (529±17 Ma) for the garnet biotite gneiss at Akarui point, in the vicinity region of Oku-iwa Rock, published by Shiraishi *et al*. (2003). The U-Pb zircon age is adopted as metamorphism age in the following discussion.

Based on present and previously published geochronological data, the cooling history of Oku-iwa Rock is illustrated in Fig. 5. The granodioritic precursor for the HB

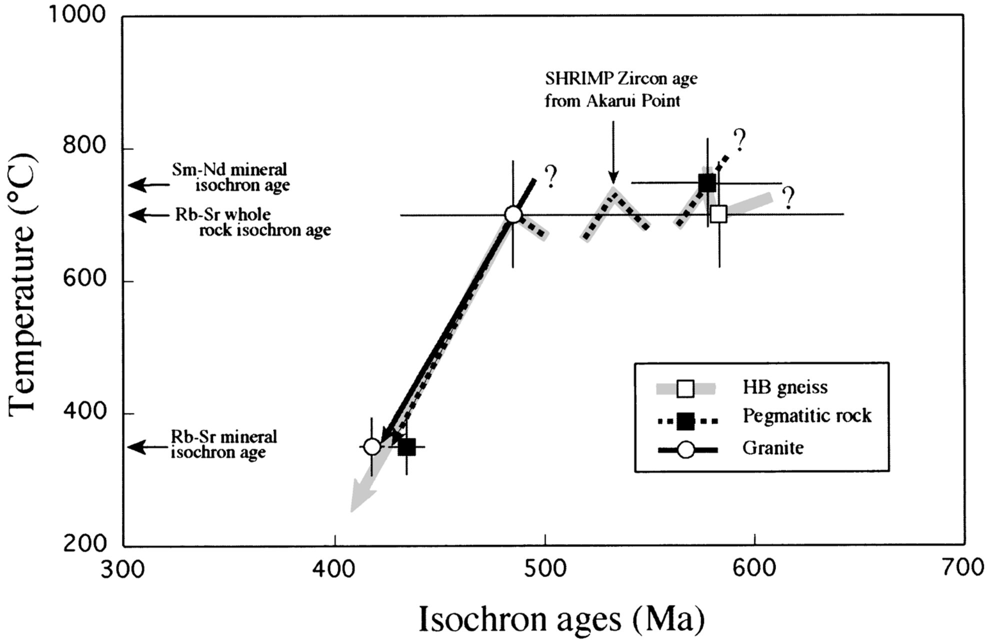

Fig. 5. Temperature versus isochron ages for Oku-iwa Rock. Data sources: This study, Nishi et al. (1999, 2002), Shiraishi et al. (2003). The closure temperature for Sm-Nd whole rock isochron method is not yet clarified. Furthermore, the HB gneiss formation temperature is also uncertain. Therefore, the granodioritic precursor can not be illustrated in this figure.

gneiss initially formed at 674 Ma (Nishi *et al.*, 2002). The temperature of the granodioritic rocks was gradually lowered, and reached the closure temperature of the Rb-Sr whole rock system (*ca.* 700°C; Harrison *et al.*, 1979) at 583 Ma (Nishi *et al.*, 2002). At 578 Ma, the original melt of pegmatitic HB gneisses injected to the HB gneiss, and the temperature rose again. The temperature of both the HB gneiss and the pegmatitic HB gneisses fell once and rose again at 529 Ma (Shiraishi *et al.*, 2003) by regional metamorphism of the transitional zone. In this time, the constituent rocks of the Oku-iwa Rock region may have been heated to over 700°C by the metamorphism. However, their isotopic composition would not have been homogenized totally, because it seems to be difficult to attain regional homogenization without activity of magma or fluid, even under metamorphism at a lower crustal level (Dickin, 1995; Kagami *et al.*, 2003; Kawano *et al.*, 2005). After regional metamorphism at 529 Ma, the rocks in the Oku-iwa Rock region cooled to below 700°C, because granitic rocks intruded at 485 Ma have fine-grained rocks at the margin of the mass (Nishi *et al.*, 2002). At 485 Ma, temperature of the gneisses and pegmatitic HB gneisses rose for the third time by intrusion of unmetamorphosed granitic rocks. After the intrusion, the constituent rocks of Oku-iwa Rock gradually cooled by uplifting and the temperature reached 310°C at 431 Ma. As a result, at least three thermal events took place in Oku-iwa Rock. There is possibility that successive thermal events happened in other areas in the LHC, and thermochronological study is extremely important for examining the formation of the Complex.

Acknowledgments

The authors are grateful to all members of JARE-36 led by Y. Ageta (Nagoya University) and all crew members of the icebreaker "*Shirase*". Special thanks are due to M. Arita (Attached high school of Hiroshima University) and K. Naito (Geological Survey of Japan) for their collaboration in the field work. We would like to express our thanks to A. Yamada (Niigata University) for measurement of isotope ratios. We acknowledge T. Miyamoto (Kyushu University) and A. Kamei (Shimane University) for their critical reviews of the manuscript.

References

Asami, M., Suzuki, K. and Adachi, M. (1997): The U and Pb analytical data and CHIME dating of monazites from metamorphic rocks of the Rayner, Lützow-Holm, Yamato-Bergica and Sør Rondane Complexes, East Antarctica. Proc. NIPR Symp. Antarct. Geosci., **10**, 130–152.

Burton, K.W. and O'Nions, R.K. (1990): The time scale and mechanism of granulite formation at Kurunegala, Sri Lanka. Contrib. Mineral. Petrol., **106**, 66–89.

Dickin, A.P. (1995): Radiogenic Isotope Geology. Cambridge, Cambridge Univ. Press, 490 p.

Goldberg, S.A. and Dallmeyer, R.D. (1997): Chronology of Paleozoic metamorphism and deformation in the Blue Ridge Thrust Complex, North Carolina and Tennessee. Am. J. Sci., **297**, 488–526.

Harrison, T.M., Armstrong, R.L., Naeser, C.W. and Harakal, J.E. (1979): Geochronology and thermal history of the Coast Plutonic Complex, near Prince Rupert, British Colombia. Can. J. Earth Sci., **16**, 400–410.

Hiroi, Y., Shiraishi, K., Yanai, K. and Kizaki, K. (1983): Aluminum silicates in the Prince Olav and Sôya Coasts, East Antarctica. Mem. Natl Inst. Polar Res., Spec. Issue, **28**, 115–131.

Kagami, H., Shimura, T., Yuhara, M., Owada, M., Osanai, Y. and Shiraishi, K. (2003): Resetting and closing condition of Rb-Sr whole-rock isochron system: some samples of metamorphic and granitic rocks from the Gondwana super-continent and Japan Arc. Polar Geosci., **16**, 227–242.

Kamei, A., Owada, M., Hamamoto, T., Osanai, Y., Yuhara, M. and Kagami, H. (2000): Isotopic equilibration ages for the Miyanohara tonalite from the Higo metamorphic belt in central Kyushu, Southwest Japan: Implications for the tectonic setting during the Triassic. Isl. Arc, **9**, 97–112.

Kawano, Y. (1994): Calculation program for isochron ages of Rb-Sr and Sm-Nd systems, using personal computer. Geoinformatics, **5**, 13–19 (in Japanese with English abstract).

Kawano, Y., Nishi, N. and Ishisaka, T. (1999): Preparation of samples for Sr and Nd isotopic analysis at petrochemical laboratory. J. Fac. Cul. Edu. Saga Univ., **4**, 139–146 (in Japanese with English abstract).

Kawano, Y., Meno, A., Nishi, N. and Kagami, H. (2005): Geochemistry of the pre/sys-metamorphic granite in the Ongul Islands, East Antarctica. Polar Geosci., **18**, 114–129.

Lugmair, G.W. and Marti, K. (1978): Lunar initial $^{143}Nd/^{144}Nd$: differential evolution of the lunar crust and mantle. Earth Planet. Sci. Lett., **39**, 349–357.

Nakai, Y., Kano, T. and Yoshikura, S. (1981): Explanatory text of geological map of Oku-iwa Rock, Antarctica. Antarctic Geological Map Series, Sheet 22. Tokyo, Natl Inst. Polar Res.

Nishi, N., Kawano, Y. and Kagami, H. (1999): Preliminary result for the Rb-Sr mineral isochron ages of granitic rocks from Cape Omega and Oku-iwa Rock, Prince Olav Coast, East Antarctica. Polar Geosci., **12**, 157–165.

Nishi, N., Kawano, Y. and Kagami, H. (2002): Rb-Sr and Sm-Nd isotopic geochronology of the granitoid and hornblende biotite gneiss from Oku-iwa Rock in the Lützow-Holm Complex, East Antarctica. Polar Geosci., **15**, 46–65.

Nishimura, S. and Mogi, T. (1986): The interpretation of discordant ages of some granitic bodies. J. Geotherm. Res. Soc. Jpn., **8**, 145–164.

Osanai, Y., Shiraishi, K., Takahashi, Y., Ishizuka, H., Tainosho, Y., Tsuchiya, N., Sakiyama, T. and Kodama,

S. (1992): Geochemical characteristics of metamorphic rocks from the Central Sør Rondane Mountains, East Antarctica. Progress in Antarctic Earth Science, ed. by Y. Yoshida *et al*. Tokyo, Terra Sci. Publ., 17–27.

Shibata, K., Yanai, K. and Shiraishi, K. (1986): Rb-Sr whole-rock ages of metamorphic rocks from eastern Queen Maud Land, East Antarctica. Mem. Natl Inst. Polar Res., Spec. Issue, **43**, 133–148.

Shimura, T., Fraser, G.L., Tsuchiya, N. and Kagami, H. (1998): Genesis of the migmatites of Breidvågnipa, East Antarctica. Mem. Natl Inst. Polar Res., Spec. Issue, **53**, 109–136.

Shiraishi, K., Ellis, D.J., Hiroi, Y., Fanning, C.M., Motoyoshi, Y. and Nakai, Y. (1994): Cambrian orogenic belt in East Antarctica and Sri Lanka: implications for Gondwana assembly. J. Geol., **102**, 47–65.

Shiraishi, K., Hokada, T., Fanning, C.M., Misawa, K. and Motoyoshi, Y. (2003): Timing of thermal events in eastern Dronning Maud Land, East Antarctica. Polar Geosci., **16**, 76–99.

Steiger, R.H. and Jäger, E. (1977): Subcommision on geochronology: Convention on the use of decay constants in geo- and cosmo-chronology. Earth Planet. Sci. Lett., **36**, 359–362.

Tanaka, T., Togashi, S., Kamioka, H., Amakawa, H., Kagami, H. and 14 other authors (2000): JNdi-1: a neodymium isotopic reference in consistency with LaJolla neodymium. Chem. Geol., **168**, 279–281.

Winkler, H.G.F. (1979): Graphical representation of metamorphic mineral parageneses. Petrogenesis of Metamorphic Rocks, 5th ed. New York, Springer, 31–54.

York, D. (1966): Least squares fitting of a straight line. Can. J. Phys., **44**, 1079–1086.