LETTER

Post-kinematic lamprophyre from the southwestern part of Sør Rondane Mountains, East Antarctica: Constraint on the Pan-African suture event

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The Sør Rondane Mountains was situated within the collision zone between the West and East Gondwana during the Pan-African event. The mountains are made up of high-grade metamorphic rocks and various kinds of intrusive rocks. Here, we report the newly found post-kinematic lamprophyre (minette) collected from the southwestern part of Sør Rondane Mountains. The minette intruded along normal faults and has no sings of any metamorphism. The K-Ar dating of biotite separated from the minette gives an age of 563 ± 14 Ma. Considering mode of occurrence, age data and geochemical signatures, the minette intruded in the within-plate tectonic setting and the timing of magma activity would start after the suture event related to the formation of Gondwana supercontinent.

Keywords: Minette, Pan-African suture, K-Ar biotite age, Gondwana supercontinent

INTRODUCTION

The Sør Rondane Mountains (22°E–28°E, 71°40′S–72°20′S), Eastern Dronning Maud Land, East Antarctica has been situated within a collision zone for the formation of Gondwana supercontinent during the Pan-African period (Shiraishi et al., 1994; Jacobs et al., 2003; Meert, 2003; Asami et al., 2005; Shiraishi et al., 2008). The analysis of metamorphic and magmatic processes in this region, therefore, leads to understand the formation processes of the Gondwana supercontinent. The high-grade metamorphic event corresponding to the collision-type metamorphism occurred between 650 Ma and 600 Ma (Shiraishi et al., 2008). Ikeda et al. (1995) described the post-kinematic mafic dikes containing the high-K dolerite and lamprophyre, and discussed their petrogenesis using petrochemical data. According to Ikeda et al. (1995), the mafic magmatism occurred in a within-plate tectonic setting after termination of the Pan-African suture event.

The ages of dolerite dikes that were dated using K-Ar and Ar-Ar whole-rock methods range from 530 Ma to 430 Ma (Takigami and Funaki, 1991; Shiraishi et al., 1997). Some of dated samples have experienced weak metamorphism (Takigami and Funaki, 1991). We found biotite-bearing lamprophyre (minette) from the southwestern part of Sør Rondane Mountains (Widerøefjellet; Fig. 1) and this rock is free from any metamorphism. To obtain more precise age of the post-kinematic mafic magmatism, we determined the K-Ar biotite age of the minette. In addition to this minette, another unmetamorphosed minette that occurs at the southern part of Lunckeryggen (Fig. 1) was also geochemically studied.

In this paper, we address geochemical and geochronological study of the minettes taken from two locations in the southwestern part of Sør Rondane Mountains and discuss the timing of the post-collisional magmatism. The petrological and geochronological investigation of intrusive rocks provides us important information to understand the crustal evolution not only of the Sør Rondane Mountains but also of the Gondwana supercontinent.
GEOLOGICAL OUTLINES

The Sør Rondane Mountains consists of greenschist- to granulite-facies metamorphic rocks and various kinds of intrusive rocks (Shiraishi et al., 1991; Asami et al., 1992; Osanai et al., 1992; Tainosho et al., 1992). The main structural features of the metamorphic rocks are controlled by the east-west trend of the foliations and fold axes (Toyoshima et al., 1995). The east-west trending large shear zone (Main Shear Zone) appears in the southwestern part of the mountains (Fig. 1; Shiraishi et al., 1991). Metamorphosed tonalite (meta-tonalite) is exposed in the southern part of the Main Shear Zone, whereas banded gneisses of felsic to intermediate compositions with minor amounts of pelitic and mafic rocks and various intrusive stocks mainly crop out in the northern part of the Main Shear Zone (Fig. 1). The metamorphic grade changes from granulite facies in the central to northeastern region to greenschist to amphibolite facies in the southwestern region (Osanai et al., 1992). The post-kinematic intrusive rocks, granitic stocks and mafic dikes, intrude the whole area of Sør Rondane Mountains. The granitic stocks with various sizes locally give distinct thermal effects to the host gneisses (Asami et al., 1992). The mafic dikes, dolerite and lamprophyre (mostly minette) sporadically intruded into the host gneisses (Ikeda et al., 1995).

The SHRIMP U-Pb zircon ages for the metamorphic and igneous rocks from the whole area of Sør Rondane Mountains are reported by Shiraishi et al. (2008). The over-growth rim of zircon from the high-grade banded gneiss is dated around 650 Ma to 600 Ma. The granitic stock (Vengen granite) gives \( \sim 564 \) Ma as a magmatic age. The Rb-Sr whole-rock isochrons of other granitic stocks indicate ages between 530 Ma and 500 Ma (Takahashi et al., 1990; Tainosho et al., 1992). The K-Ar and Ar-Ar whole-rock methods for the dolerite give ages from 530 Ma to 430 Ma (Takigami and Funaki, 1991; Shiraishi et al., 1997).

DESCRIPTION, GEOCHEMISTRY AND GEOCHRONOLOGY OF ANALYZED SAMPLES

The minette is collected from two locations, Lunckeryggen and Widerøefjellet, in the southwestern part of Sør Rondane Mountains (Fig. 1). In both locations, the minette occurs as dikes with few centimeters to meters in width (Fig. 2). Generally, the dikes show dark color and have chilled margins. The minette newly described here is free from any metamorphic features (Fig. 3).

The minette from Lunckeryggen (Lunckeryggen minette) intruded into both of the meta-tonalite and the Lunckeryggen granite that is one of the post-kinematic stocks. The granite stocks with various sizes locally give distinct thermal effects to the host gneisses (Asami et al., 1992). The mafic dikes, dolerite and lamprophyre (mostly minette) sporadically intruded into the host gneisses (Ikeda et al., 1995).

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The minette from Widerøefjellet is situated at 35 km to the west of Lunckeryggen (Fig. 1), and intruded along normal faults in the biotite granodiorite at the southeastern end of Widerøefjellet (Fig. 2c). This minette (Widerøefjellet minette) possesses vesicles that are filled by calcite inside the minette. The dikes strike E-W and dip moderately to the south (40°-50°) (Fig. 2c). The minette bears phenocrysts of biotite, clinopyroxene and feldspars. Biotite phenocrysts exhibit almost euhedral shapes and are fresh. Olivine phenocrysts are locally identified by their euhedral shape, and are completely replaced by amphibole that probably formed during cooling. Opaque minerals occur as accessory minerals (Fig. 3b).

Geochemical analyses were performed by XRF at the Center for Instrumental Analyses, Yamaguchi University for major and some trace elements, and by ICP-MS at Activation Laboratory Ltd for trace elements including rare earth elements (REE). Chemical compositions of the two minette samples are listed in Table 1. SiO₂ contents of the minettes range from 46 wt% to 54 wt%, and are plotted within the field of alkaline rocks in the TAS diagram and ultra-K field in the K₂O - Na₂O diagram (recalculated to total oxides =100 wt%, Fig. 4a and 4b). The minettes newly described here tend to show high concentration of total alkali, especially in potassium compared with the previously reported lamprophyre of the Sør Rondane Mountains (Fig. 4a and 4b).

The Lunckeryggen and Widerøefjellet minettes are characterized by high abundances of LIL elements and REE, especially Rb, Ba and Sr (Table 1). The trace element abundances normalized to primitive mantle (Sun and McDonough, 1989) of both minettes are similar to each other (Fig. 4c). The patterns display enrichment of large ion lithophile elements (LILE) and depression of high strength field elements (HFSE) with Nb and Ta negative anomalies similar to the previously reported lamprophyre (Ikeda et al., 1995, Fig. 4c). The Widerøefjellet minette possesses low abundances of incompatible elements and high Mg-values rather than the Lunckeryggen mi-
Post-kinematic lamprophyre, East Antarctica

We separated biotite from the Widerøefjellet minette for K–Ar dating. The K–Ar dating was conducted by Activation Laboratory Ltd. The age is calculated using decay constants $\lambda_{\beta} = 0.4962/Ga$ and $\lambda_{\epsilon} = 0.0581$, and isotopic abundance ratio $^{40}\text{K}/^{40}\text{K} = 0.0001167$ (Steiger and Jäger, 1977). The result gives an age of 563 Ma ± 14 Ma (Table 2). This is the oldest age among the post-kinematic mafic dikes from the Sør Rondane Mountains.

### DISCUSSION AND CONCLUSIONS

The SHRIMP dating for the banded gneisses from the whole area of the Sør Rondane Mountains reveals that the timing of peak metamorphism occurs during 650 Ma to 600 Ma whose ages correspond with the timing of Pan-African suture event (Shiraishi et al., 2008). The Lunckeryggen and Widerøefjellet minettes distinctly cut the metamorphic foliations and have chilled margins. The Widerøefjellet minette possesses vesicles or amygdales (Fig. 2d); thereby, suggesting this minette was intruded at a shallow level of the crust, probably close to the surface and was rapidly cooled. The K–Ar biotite age thus probably represents the timing of intrusion. To take into account the previously reported younger ages of intrusive rocks, the post-collision magma activity in the Sør Rondane Mountains began at the age of 563 Ma ± 14 Ma as constrained by the studied minette.

The minette magmas studied here show negative Nb, Ta and Ti anomalies and the LILE/HFSE ratios are higher than those of Oceanic Island Basalts (OIB) (Fig. 4c). Such geochemical features resemble the previously reported lamprophyres from the Sør Rondane Mountains (Fig. 4c, Ikeda et al., 1995; Owada et al., 2008). These lamprophyres are plotted in the within-plate field and a part of the island arc field that is close to the within-plate field on some discrimination diagrams. Based on these geochemical features, Ikeda et al. (1995) interpreted that the lamprophyre has been formed in a within-plate tectonic setting by the mixing of subduction-related materials (e.g., slab-derived fluids, melting product of subducted crustal rocks, or reaction with fossil wedge mantle) at mantle depth.

The age of the Widerøefjellet minette (563 Ma) is the same as the SHRIMP age of the Vengen granite (~564 Ma) that is located 12 km to the northwest of the Widerøefjellet minette (Fig. 1). The Vengen granite geochemically resembles the within-plate granite (Li et al., 2003). In addition, the Lunckeryggen granite is regarded as a post-collisional magmatism in terms of its geochemical signatures (Owada et al., 2006). Considering the occurrence, geochemistry and geochronology of the newly found minettes combined with the metamorphic ages by the SHRIMP dating, the age of ~563 Ma can be correlated with the timing of initial post-kinematic magmatism in the Sør Rondane Mountains. In other words, the magma activities of the minette may have initiated at 563 Ma ± 14 Ma in the within-plate setting after the suture event related to the formation of Gondwana supercontinent.

### Table 1. Chemical compositions of the minette from Lunckeryggen and Widerøefjellet

<table>
<thead>
<tr>
<th>Site</th>
<th>Lunckeryggen</th>
<th>Widerøefjellet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sp. No.</td>
<td>M0801</td>
<td>M0901</td>
</tr>
<tr>
<td></td>
<td>0801</td>
<td>0802A</td>
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<tr>
<td>Total Fe as Fe$_2$O$_3$ ppm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SiO$_2$</td>
<td>53.62</td>
<td>49.23</td>
</tr>
<tr>
<td>TiO$_2$</td>
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<td>AI$_2$O$_3$</td>
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<tr>
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<tr>
<td>MnO</td>
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<tr>
<td>MgO</td>
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<td>5.37</td>
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<tr>
<td>CaO</td>
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<tr>
<td>Na$_2$O</td>
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<tr>
<td>K$_2$O</td>
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</tr>
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<td>P$_2$O$_5$</td>
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</tr>
<tr>
<td>LOI</td>
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<td>1.39</td>
</tr>
<tr>
<td>Total</td>
<td>97.70</td>
<td>98.65</td>
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</table>
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