Proc. NIPR Symp. Antarct. Geosci., 4, 1-8, 1990

Rb-Sr AND K-Ar WHOLE ROCK AGES OF THE PLUTONIC BODIES FROM THE SØR RONDANE MOUNTAINS, EAST ANTARCTICA

Yuhei TAKAHASHI[1], Yoji ARAKAWA[2], Tohru SAKIYAMA[3]*, Yasuhito OSANAI[4] and Hiroshi MAKIMOTO[1]

[1]*Geological Survey of Japan, 1-3, Higashi 1-chome, Tsukuba 305*
[2]*Institute of Geoscience, University of Tsukuba, 1-1, Tennodai 1-chome, Tsukuba 305*
[3]*Faculty of Science, Hiroshima University, 1-89, Higashi-Sendamachi 1-chome, Naka-ku, Hiroshima 730*
[4]*Department of Earth Science and Astronomy, Fukuoka University of Education, 729, Akama, Munakata 811-41*

Abstract: Rb-Sr whole rock isochron ages were determined on the two plutonic bodies from the Sør Rondane Mountains. Tonalite of the Nils Larsen Group (Nils Larsen Tonalite), being one of the representative older type intrusive rocks, gave an age of 956±39 Ma with an initial $^{87}Sr/^{86}Sr$ ratio of 0.7024. The other is the Lunckeryggen Granite, which is the most representative granite of younger type, gave an age of 525±32 Ma with an initial $^{87}Sr/^{86}Sr$ ratio of 0.7050. Two whole rock K-Ar ages on this granite were 406±20 and 415±21 Ma.

It appears from the above that tonalitic magma has been intruded in Late Precambrian and that granitic magma in Early Paleozoic. Another thermal event occurred in Middle Paleozoic. Difference of initial Sr isotopic ratios between the Nils Larsen Tonalite and the Lunckeryggen Granite may reflect the crustal development in this area.

1. Introduction

The Sør Rondane Mountains (71.5°-72.5°S, 22°-28°E) are one of the largest inland mountains in East Antarctica. The main part of the mountains consists of metamorphic rocks and plutonic rocks with minor dike rocks. Geology and petrography of plutonic rocks in this area are summarized by SAKIYAMA *et al.* (1988).

Most of isotopic ages of these metamorphic and plutonic rocks have been Late Proterozoic to Early Paleozoic (PICCIOTTO *et al.*, 1963; PASTEELS and MICHOT, 1968, 1970). However, the reliable Rb-Sr whole rock isochron ages, which are expected to suggest the emplacement of magma, are yet to be determined.

This paper presents the Rb-Sr whole rock isochron ages and the initial Sr isotopic ratios for two plutonic bodies, which are selected on the basis of the geological summary of SAKIYAMA *et al.* (1988). Two K-Ar ages of the younger granite are also presented. We will discuss the ages of the igneous activity in the Sør Rondane Mountains.

* Present address: Mitsui Mineral Development Engineering Co., 23-1, Oi 1-chome, Shinagawa-ku, Tokyo 140.

2. Geologic Setting for Dated Samples

Plutonic rocks in the western to central parts of the Sør Rondane Mountains are divided into the older type rocks and the younger type rocks (SAKIYAMA *et al.*, 1988). The older type rocks have emplaced before or during the period of the regional mylonitization (probably Early Paleozoic). They are composed of tonalite, granodiorite to granite and related quartz diorite with small amounts of sheetlike granite, granodiorite and trondhjemite. They are characterized by gneissose structure and have concordant boundaries with the surrounding metamorphic rocks. On the other hand, the younger type rocks have intruded after the regional mylonitization. They are divided into two units; syenitic rocks and granitic rocks. They occur as stocks or dykes with the discordant boundaries with the surrounding rocks.

The Rb-Sr whole rock age determinations were performed on the tonalite of the older type and the granite of the younger type. In addition, the K-Ar datings were performed on the younger type granite. Localities of rock samples for datings are shown in Fig. 1. Geological and petrographical characteristics of these rocks are described as follows.

Nils Larsen Tonalite: The tonalite is exposed in the southwestern part of the mountains. It is one of the members of the Nils Larsen Group (VAN AUTENBOER and LOY, 1972) and belongs to the older type plutonic rocks. In the present paper, this tonalite is called Nils Larsen Tonalite. It is medium- to coarse-grained biotite-horn-

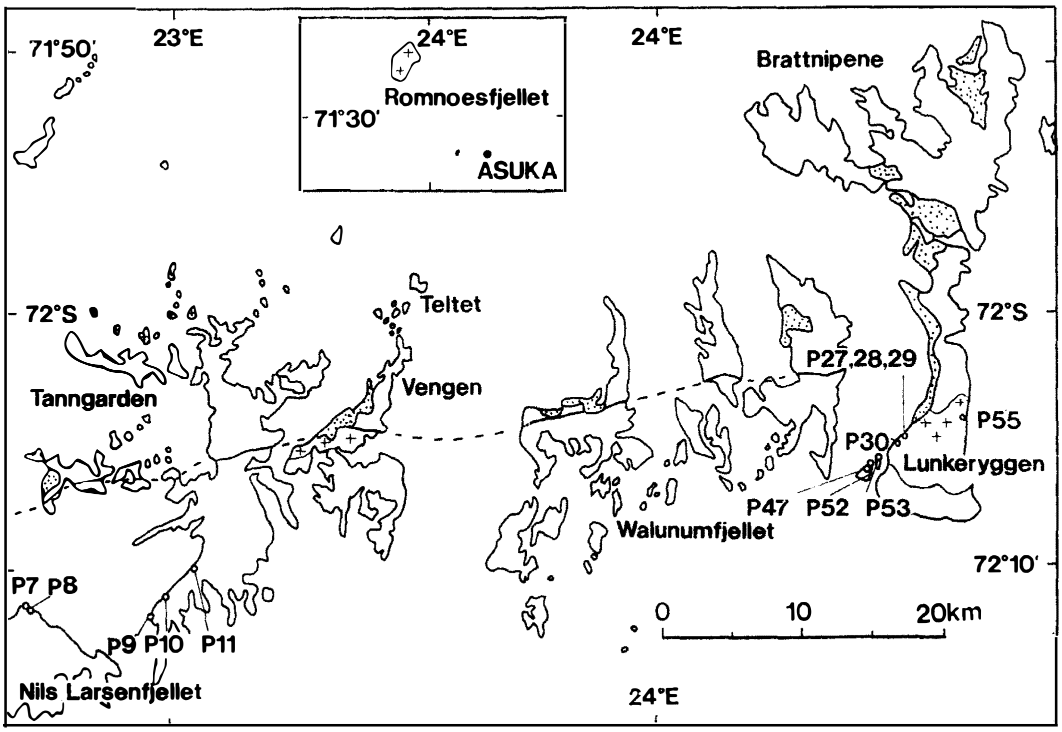

Fig. 1. Locality map for dated samples. Dotted symbols represent moraine, crossed symbols represent granite and thick solid and broken lines represent northern margin of the Main Shear Zone.

blende tonalite, and is composed mainly of plagioclase, quartz, hornblende and biotite with accessory apatite, zircon and opaque minerals. Hornblende and biotite show a preferred orientation.

Lunckeryggen Granite: The granitic stock is exposed in the southern part of Lunckeryggen in the central part of the mountains. It is massive and is composed of coarse-grained biotite granite to hornblende-biotite granite with dykes of fine-grained biotite granite. Main constituents of the coarse-grained granite are quartz, potash feldspar, plagioclase and biotite with or without hornblende. Accessories are sphene, apatite, zircon and magnetite. The fine-grained granite is composed mainly of quartz, potash feldspar, plagioclase and biotite, with accessories of sphene, apatite, fluorite, zircon and magnetite.

3. Analytical Methods

Whole rock samples weighing 0.5–1 kg were crushed, carefully split down to about 35 g then finely powdered. Rb and Sr concentrations were determined by the isotope dilution method. The $^{87}Sr/^{86}Sr$ ratio was determined by VG-Micromass MM-30 double-collector type mass spectrometer at the University of Tsukuba. All the $^{87}Sr/^{86}Sr$ ratios were normarized to the $^{86}Sr/^{88}Sr$ ratio of 0.1194. Repeated analyses of the $^{87}Sr/^{86}Sr$ ratio for the NBS 987 $SrCO_3$ standard during this study gave an average of 0.71030 ± 0.00003 ($2\sigma m$). The errors of $^{87}Rb/^{86}Sr$ ratios are estimated to be $\pm 1\%$ (1σ), and the measuring errors for $^{87}Sr/^{86}Sr$ ratio are less than 0.0035% (1σ). Errors of the calculated ages and initial ratios were quoted at 2σ level by YORK method (YORK, 1969). The decay constant of ^{87}Rb used in this work is 1.42×10^{-11}/y (STEIGER and JÄGER, 1977). The whole rock age determined by the K-Ar method was given by the Teledyne Isotopes Ltd., U.S.A.

4. Results and Discussion

4.1. *Nils Larsen Tonalite*

Rb/Sr analytical data for whole-rock samples of the Nils Larsen Tonalite are given in Table 1 and are plotted in the isochron diagram (Fig. 2). All these six samples define an isochron with an age of 852 ± 41 Ma and an initial $^{87}Sr/^{86}Sr$ ratio of 0.70291 ± 0.00016. Five samples except P30 give an age of 956 ± 39 Ma and an initial $^{87}Sr/^{86}Sr$ ratio of 0.70237 ± 0.00019. The Nils Larsen Tonalite was more or less mylonitized by

Table 1. Rb-Sr analytical data for Nils Larsen Tonalite.

Sample	Rb (ppm)	Sr (ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$
P7 (85020201C)	30.06	188.6	0.4615	0.70861
P8 (85020202)	47.99	586.0	0.2371	0.70560
P9 (85020451)	15.82	140.0	0.3273	0.70689
P10 (85020454A)	18.78	152.3	0.3570	0.70723
P11 (85020455A)	23.57	158.4	0.4310	0.70832
P30 (S87012005D)	2.91	742.5	0.0114	0.70309

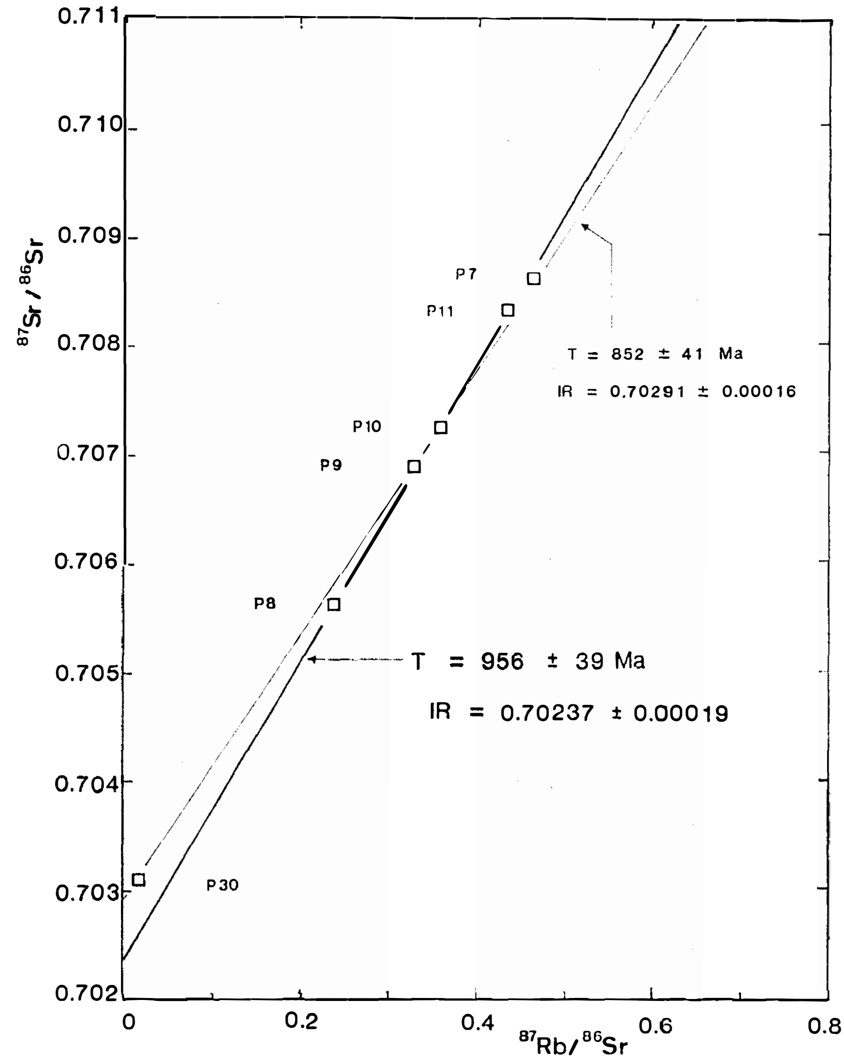

Fig. 2. Whole rock isochron diagram for the Nils Larsen Tonalite.

regional mylonitization (formation of the Main Shear Zone). This mylonitization accompanied retrogressive metamorphism such as formation of dark green schist (KOJIMA and SHIRAISHI, 1986). It seems that the metamorphism gave little effect to the Rb-Sr whole rock system because this metamorphism is weak. One sample (P30) occurs as a large xenolith in the younger granite and is located away from the other five samples. Therefore, the whole rock isochron age by five samples except P30, 956 Ma, suggests tonalitic intrusion. This age is consistent with U-Pb zircon age (about 950 Ma) of this tonalite (tonalitic gneiss of the Nils Larsen Group, PASTEELS and MICHOT, 1968).

The initial $^{87}Sr/^{86}Sr$ ratio of the tonalite was low and the chemical character was calc-alkaline in trend (SAKIYAMA *et al.*, 1988). These data suggest that this tonalite has been produced as a result of partial melting of an immature crust such as a primitive island arc.

4. 2. Lunckeryggen Granite

Four samples of coarse-grained facies and three samples of fine-granied facies of the Lunckeryggen Granite were used for analyses. These data are given in Table 2 and plotted on the isochron diagram in Fig. 3.

Four coarse-grained sampels (circles in Fig. 3) define an isochron with an age of 498.2 $\pm$ 59.4 Ma and an initial $^{87}Sr/^{86}Sr$ ratio of 0.70522 $\pm$ 0.00033, and three fine-grained samples (triangles in Fig. 3) give an age of 550.8 $\pm$ 1.6 Ma and an initial ratio of 0.70473 $\pm$ 0.00002. All seven samples show an age of 524.9 $\pm$ 31.6 Ma and an initial $^{87}Sr/^{86}Sr$ ratio of 0.70504 $\pm$ 0.00025. The age of seven sampels (525 $\pm$ 32 Ma) spans between two ages of corase-grained and fine-grained facies (498 and 551 Ma), so we adopt the value for all seven samples (525 Ma) as the age of emplacement of this granite.

The whole rock K-Ar ages on two samples of coarse-grained rocks (P52 and P55) were 415 $\pm$ 21 and 406 $\pm$ 20 Ma (Table 3), which are not concordant with the above whole rock Rb-Sr age. TAKIGAMI *et al.* (1987) reported some K-Ar and ^{40}Ar-^{39}Ar ages for metadolerite and gneiss in the Sør Rondane Mountains. They interpreted that slightly young K-Ar age (419 $\pm$ 57 Ma) for gneiss might be due to Ar loss by the secondary effects such as weathering or weak metamorphism, but they have not found a definite evidence to identify the cause. Although we have no idea to interpret these ages, we can point out that these 400–450 Ma values agree with young ages of some plutonic and metamorphic rocks around Syowa Station (SUZUKI, 1986).

VAN AUTENBOER and LOY (1972) divided the intrusive rocks into Romnaesfjellet intrusives (520 Ma) and Lunckeryggen-Tertene granites (600 Ma) based upon U-Pb zircon age. The latter is the granitic body dated in our study. The present data of 525 Ma is younger than the previous data (600 Ma) and equal to the age of the Romnaesfjellet intrusives. We need to reconstruct geochronological subdivision of younger granite by more reliable data.

The granite has an initial $^{87}Sr/^{86}Sr$ ratio of about 0.705 and has chemical characters of A-type granites which often occur in anorogenic region (COLLINS *et al.*, 1982). The initial ratio of the granite is higher than that of above mentioned tonalite. It suggests that this granitic intrusion occurred in the continental crust.

Table 2. Rb-Sr analytical data for Lunckeryggen Granite.

Sample	Rb (ppm)	Sr (ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$
Coarse-grained facies				
P27 (S87012004A)	189.2	1318.6	0.4155	0.70805
P52 (T87012007A)	229.2	690.9	0.9608	0.71223
P53 (S87012403A)	203.5	928.4	0.6347	0.70963
P55 (S87013104C)	114.0	1329.0	0.2484	0.70706
Fine-grained facies				
P28 (S87012004C)	273.7	1376.7	0.5755	0.70924
P29 (S87012004D)	211.2	1028.2	0.5947	0.70940
P47 (T87012204C)	378.4	265.0	4.146	0.73728

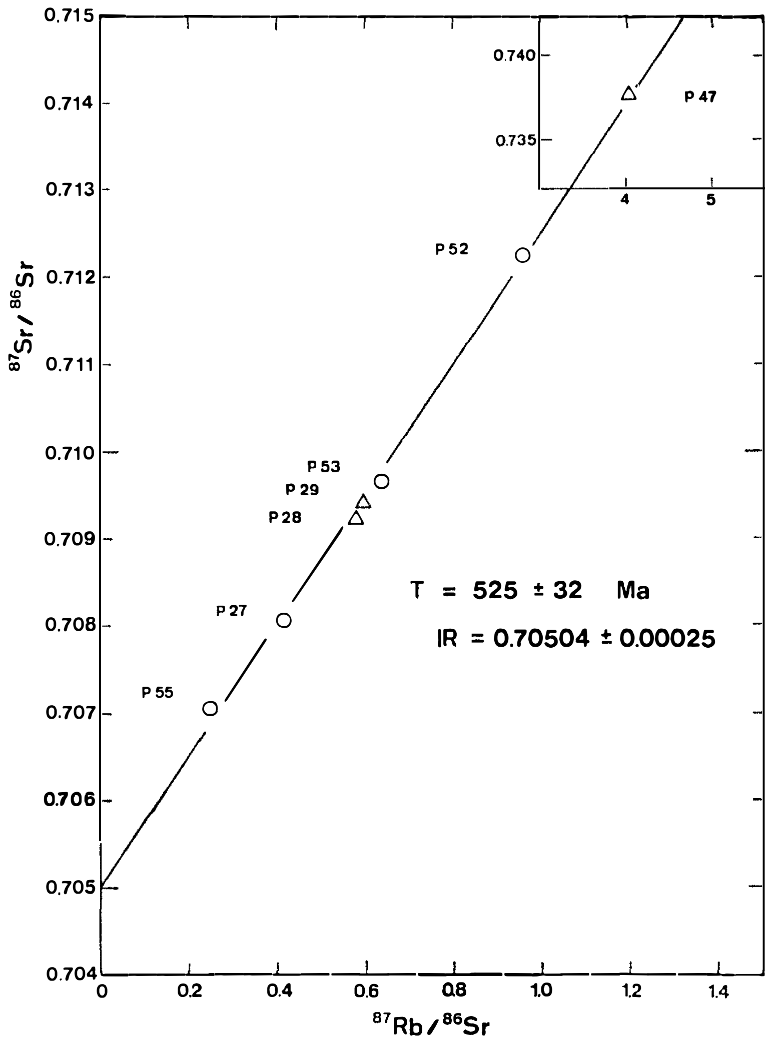

Fig. 3. Whole rock isochron diagram for the Lunckeryggen Granite. Open circles represent coarse-grained rocks and open triangles represent fine-grained rocks.

Table 3. Whole rock K-Ar ages for Lunckeryggen Granite.

Sample	Material analyzed	Isotopic Age (Ma)	$^{40}Ar^*$ (scc/g$\times 10^{-5}$)	%^{40}Ar	%K
P52 (T87012007A)	Whole rock	415±21	8.14	96.1	4.49
			8.09	95.3	4.46
P55 (S87013104C)	Whole rock	406±20	9.89	95.7	5.47
			9.36	95.9	5.46
			9.98	95.1	
			9.47	93.3	

Decay constants are after STEIGER and JÄGER (1977).
Analyst: Teledyne Isotope Ltd.

5. Summary

The Nils Larsen Tonalite of the older type intrusives gave Rb-Sr whole rock age of about 950 Ma with low initial $^{87}Sr/^{86}Sr$ ratio (0.7024). On the other hand, the Lunckeryggen Grainte of the younger type intrusives gave Rb-Sr whole rock age of 525 Ma with high initial $^{87}Sr/^{86}Sr$ ratio (0.7050). The K-Ar whole rock ages of the granite are 406 and 415 Ma which are discordant with the above Rb-Sr whole rock isochron age.

These data suggest that tonalitic magma has been intruded in Late Precambrian and that granitic magma in Early Paleozoic. Another thermal event occurred in Middle Paleozoic (*ca.* 400 Ma). Difference of initial Sr isotopic ratios between the Nils Larsen Tonalite and the Lunckeryggen Granite may reflect the crustal development in this area.

Acknowledgments

We wish to thank Drs. K. SHIRAISHI and S. KOJIMA for providing some samples and valuable discussion on the field occurrence. We are also grateful to Prof. T. FUJII, University of Tsukuba, for critical reading of the manuscript.

References

COLLINS, W. J., BEAM, S. D., WHITE, A. J. R. and CHAPPELL, B. W. (1982): Nature and origin of A-type granites with particular reference to southeastern Australia. Contrib. Mineral. Petrol., **80**, 189–200.

KOJIMA, S. and SHIRAISHI, K. (1986): Note on the geology of the western part of the Sør Rondane Mountains, East Antarctica. Mem. Natl Inst. Polar Res., Spec. Issue, **43**, 116–131.

PASTEELS, P. and MICHOT, J. (1968): Nouveaux résultats géochronologiques obtenus par la méthode U-Pb sur des zircons des monts Sör-Rondane (Antarctique). Ann. Soc. Géol. Belg., **91**, 283–303.

PASTEELS, P. and MICHOT, J. (1970): Uranium-lead radioactive dating and lead isotope study on sphene and K-feldspar in the Sør-Rondane Mountains, Dronning Maud Land, Antarctica. Eclogae Geol. Helv., **63**, 239–254.

PICCIOTTO, E., DEUTSCH, S. and PASTEELS, P. (1963): Isotopic ages from the Sør-Rondane Mountains, Dronning Maud Land. Antarctic Geology, ed. by R. J. ADIE. Amsterdam, North-Holland, 570–578.

SAKIYAMA, T., TAKAHASHI, Y. and OSANAI, Y. (1988): Geological and petrological characters of the plutonic rocks in the Lunckeryggen-Brattnipene region, Sør Rondane Mountains, East Antarctica. Proc. NIPR Symp. Antarct. Geosci., **2**, 80–95.

STEIGER, R.H. and JÄGER, E. (1977): Subcomission on geochronology; Convention on the use of decay constants in geo- and cosmochronology. Earth Planet. Sci. Lett., **36**, 359–362.

SUZUKI, M. (1986): Nendai to chishitsu kubun (Geochronology and geological subdivision). Nankyoku no Kagaku, **5**. Chigaku (Science in Antarctica, 5. Earth Sciences), ed. by Kokuritsu Kyokuchi Kenkyûjo. Tokyo, Kokon Shoin, 10–23.

TAKIGAMI, Y., KANEOKA, I. and FUNAKI, M. (1987): Age and paleomagnetic studies for intrusive and metamorphic rocks from the Sør Rondane Mountains, Antarctica. Proc. NIPR Symp. Antarct. Geosci., **1**, 169–177.

VAN AUTENBOER, T. and LOY, W. (1972): Recent geological investigations in the Sør-Rondane Mountains, Belgicafjella and Sverdrupfjella, Dronning Maud Land. Antarctic Geology and Geo-

physics, ed. by R. J. ADIE. Oslo, Universitetsforlaget, 563–571.
YORK, D. (1969): Least-squares fitting of a straight line with correlated errors. Earth Planet. Sci. Lett., **5**, 320–324.

(Received November 1, 1989; Revised manuscript received April 19, 1990)