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Rb-Sr WHOLE-ROCK AGES OF METAMORPHIC ROCKS FROM EASTERN QUEEN MAUD LAND, EAST ANTARCTICA

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Abstract: Rb-Sr whole-rock isochron ages were determined on the Lützow-Holm and Yamato-Belgica Complexes from eastern Queen Maud Land. Metamorphic rocks from East Ongul Island, Nesöya, Sinnan Rocks and the Yamato Mountains gave ages ranging between 683.0 and 722.1 Ma. Rocks from Skarvsnes gave older ages of 1131 and 1033 Ma. All these ages are interpreted to represent the times of high-grade metamorphism. The Skarvsnes area was apparently not affected by the 700 Ma metamorphism.

The initial $^{87}Sr/^{86}Sr$ ratios of metamorphic rocks show a considerable variation on local as well as regional scale. The higher initial ratios of the Yamato Mountains suggest that the protolith of the Yamato-Belgica Complex is older than that of the Lützow-Holm Complex.

1. Introduction

Eastern Queen Maud Land, East Antarctica, is underlain by high-grade metamorphic rocks associated with various kinds of plutonic rocks. Recent geological and petrological studies have revealed the outline of the nature and history of metamorphism in this district. In particular, two contrasting complexes, Lützow-Holm Complex and Yamato-Belgica Complex, have been recognized (HIROI *et al.*, 1984; SHIRAISHI *et al.*, 1985). The detailed chronological framework of eastern Queen Maud Land, however, has not been established, because only few Rb-Sr whole-rock and U-Pb ages are available. Geochronological studies suggest the existence of the Archean crust as old as 3500 Ma in Enderby Land (DEPAOLO *et al.*, 1982), which extends to east of Queen Maud Land. Thus the age relationship between the two lands is of particular importance in elucidating the geological evolution of East Antarctica.

This paper presents Rb-Sr whole-rock ages for metamorphic rocks from several regions of the eastern Queen Maud Land, and discusses the time and nature of metamorphic events.

2. Geological Setting

The late Proterozoic metamorphic terrain in eastern Queen Maud Land is divided into two contrasting complexes; Lützow-Holm Complex to the northeast and Yamato-Belgica Complex to the southwest (Fig. 1; HIROI *et al.*, 1984; SHIRAISHI *et al.*, 1985; HIROI and SHIRAISHI, 1986). To the east of the Lützow-Holm Complex, the Proterozoic Rayner Complex which is considered to be the re-metamorphosed Archean Napier

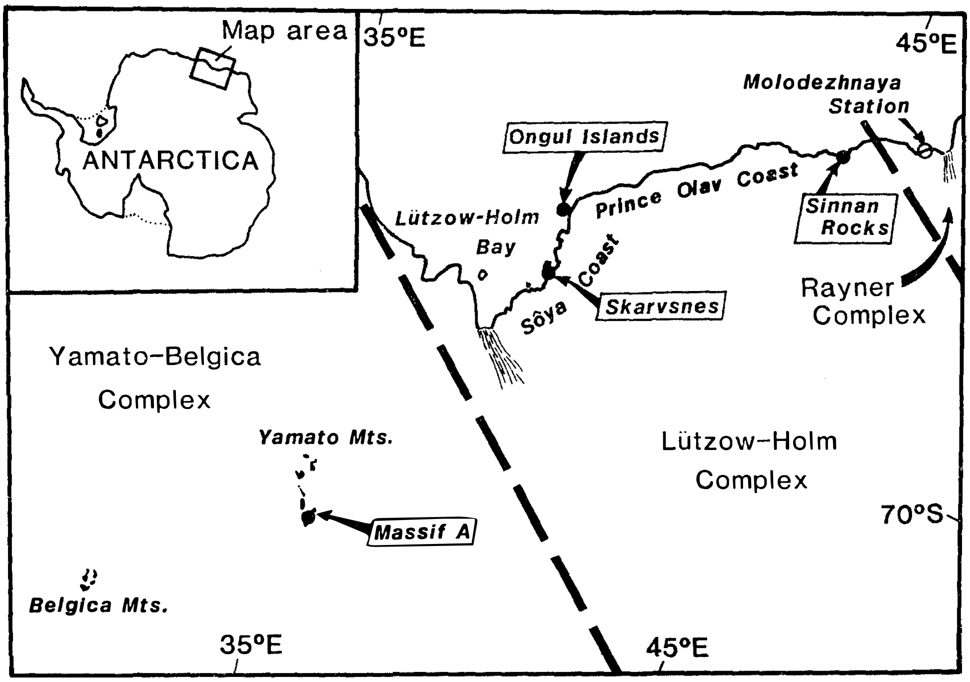

Fig. 1. Map of eastern Queen Maud Land showing sample localities. Thick broken lines show inferred boundaries between complexes.

Complex is distributed (KAMENEV, 1972; GREW, 1978; ELLIS, 1983). The boundaries between these complexes are covered by the ice sheet. The Lützow-Holm Complex comprises well-layered gneisses of various compositions and granitic to granodioritic migmatite of anatectic origin (HIROI *et al.*, 1983b). It is characteristic that ultramafic rocks occur in the gneiss sequence of the western part of the complex (HIROI *et al.*, 1986). The regional metamorphism of the complex is the medium-pressure type, grading up progressively from the upper amphibolite-facies to the granulite-facies toward the southwest (HIROI *et al.*, 1983a, b; SHIRAISHI *et al.*, 1984; MOTOYOSHI, 1986). Moreover, detailed petrology revealed that the rocks experienced the highest-pressure condition in the early P-T history prior to the maximum temperature stage (HIROI *et al.*, 1984, 1986; SHIRAISHI *et al.*, 1985). Plutonism in the complex is limited to the local intrusive charnockite except for extensive early Paleozoic granite (YOSHIDA, 1978).

In the Yamato-Belgica Complex, igneous activity is widespread and characteristic. The complex is now composed mainly of the amphibolite-facies rocks of quartzofeldspathic and basic composition with minor amounts of pelitic and calcareous rocks. Granulite-facies rocks of intermediate to basic compositions accompanied with a minor amount of calcareous composition occur locally and are partly included in the syenite body (SHIRAISHI *et al.*, 1983). It is in striking contrast to the Lützow-Holm Complex that the ultramafic rocks have not been found in the Yamato-Belgica Complex. Although the genetic relationship between the amphibolite- and granulite-facies rocks is not well known, the granulite-facies rocks belong to the low-pressure type (ASAMI and SHIRAISHI, 1985; SHIRAISHI *et al.*, 1985; HIROI and SHIRAISHI, 1986).

Thus, the metamorphic complexes in eastern Queen Maud Land show contrasting features in the source rock compositions, in the type of regional metamorphism and in the igneous activity. Recently, a continent-continent collision model has been adopted to interpret the formation of such "paired" metamorphic complexes (HIROI *et al.*, 1984; SHIRAISHI *et al.*, 1985; HIROI and SHIRAISHI, 1986).

Early Paleozoic granite is widely distributed throughout eastern Queen Maud Land (SAITO and SATO, 1964; YANAI and UEDA, 1974; SHIRAISHI *et al.*, 1983; HIROI *et al.*, 1983b). Mineral ages including Rb-Sr mineral isochron on the metamorphic rocks from both complexes concentrate between 350 and 560 Ma, probably resulting from the re-heating by the granite intrusion (HIROI *et al.*, 1983a, b; SHIBATA *et al.*, 1985).

The areas selected for Rb-Sr whole-rock dating are East Ongul Island and Nesöya, Skarvsnes, Sinnan Rocks, and Yamato Mountains, of which the geological sketch maps are shown in Figs. 2, 5, 8 and 10, respectively. References on geology and petrography of these areas are given in the figures, and mineral assemblages of dated rocks in the appendix.

3. Analytical Methods

Whole-rock samples weighing 0.6–4 kg were crushed, carefully split down to about 100 g, then finely powdered. Rb and Sr concentrations were determined either by isotope dilution or X-ray fluorescence method. Isotope dilution and $^{87}Sr/^{86}Sr$ ratio analyses were carried out by a Micromass 54E mass spectrometer. The uncertainty in the $^{87}Rb/^{86}Sr$ ratio was estimated to be ± 2 and 5% for isotope dilution and X-ray fluorescence methods, respectively, and that in the $^{87}Sr/^{86}Sr$ ratio to be $\pm 0.015\%$. Replicate analyses of the E and A standard during this study gave an average $^{87}Sr/^{86}Sr$ ratio of 0.70808 ± 0.00002 (1σ).

Isochron ages were calculated by the least-squares method of YORK (1966), and errors in age and initial ratio were given on 2σ level. The Mean Square of Weighted Deviates (MSWD) was also calculated for each isochron to assess the scatter of data points. The cut-off level between isochron and errorchron is placed at 2.5 (BROOKS *et al.*, 1972). If an MSWD exceeds 2.5, then the line is identified as errorchron, and the geological scatter outside the limit of experimental error is assumed to exist. The decay constant used for $^{87}Rb\lambda$ is 1.42×10^{-11}/y. Rb-Sr ages quoted in this paper are recalculated by this constant.

4. Results

Rb-Sr analytical data for 48 whole-rock samples are given in Table 1 and plotted on isochron diagrams in Figs. 3, 4, 6, 9 and 11.

4.1. *East Ongul Island*

Seventeen samples were taken from an area 1.0×1.3 km wide in East Ongul Island (Fig. 2). Excluding five samples (0201 to 0203, 0205 and 0206) from a single outcrop, 12 samples are plotted on an isochron diagram (Fig. 3). Of these, 10 samples define an isochron of 683.1 ± 13.2 Ma with an initial $^{87}Sr/^{86}Sr$ ratio of 0.70471 ± 0.00011. The MSWD for this isochron is 0.80, and thus it is considered as the true isochron. Two samples (2012 and 0103) plot far off the isochron and not included in the age calculation.

Table 1. Rb-Sr analytical data for metamorphic rocks from eastern Queen Maud Land.

Sample No.	Rock	Rb* (ppm)	Sr* (ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$
East Ongul Island					
1701	Scapolite-bearing anorthositic gneiss	12.3	739	0.048	0.70526
2002	Hornblende-orthopyroxene gneiss	107	434	0.714	0.71202
2002-1	Garnet-hornblende-orthopyroxene gneiss	121	343	1.02	0.71494
2004	Biotite-hornblende gneiss	49.17	620.6	0.2294	0.70697
2008	Biotite-orthopyroxene amphibolite	29.73	423.0	0.2035	0.70670
2012	Garnet quartzofeldspathic gneiss	183.3	219.5	2.417	0.72601
2016	Biotite-hornblende-orthopyroxene gneiss	3.983	412.5	0.0280	0.70483
EO125	Granitic gneiss	183.4	217.4	2.443	0.72789
80B-1	Garnet-orthopyroxene-biotite gneiss	165.0	124.3	3.843	0.74212
0103	Biotite-hornblende gneiss	93.41	434.9	0.6220	0.71376
					0.71375
0302	Granitic gneiss	155.0	177.6	2.526	0.72923
2502	Biotite-hornblende gneiss	143.6	350.8	1.185	0.71647
0201	Orthopyroxene granulite	9.53	89.6	0.308	0.70750
0202	Orthopyroxene-hornblende granulite	9.98	404	0.072	0.70583
0203	Anorthositic gneiss	9.99	1180	0.025	0.70506
0205	Biotite-orthopyroxene-hornblende granulite	14.4	115	0.363	0.70795
0206	Biotite-hornblende gneiss	36.0	629	0.166	0.70571
Nesöya					
0101-2	Biotite-hornblende gneiss	73.63	417.0	0.5113	0.71281
0102A	Biotite-hornblende gneiss	105.5	701.3	0.4354	0.71122
0102B	Quartzofeldspathic gneiss	151.0	522.1	0.8378	0.71466
0107	Biotite gneiss	159.9	565.8	0.8186	0.71646
1802	Garnet-biotite gneiss	186.0	97.17	5.542	0.76297
					0.76290
2802	Hornblende gneiss	56.50	619.7	0.2640	0.70870
West Ongul Island					
68-2008	Granitic pegmatite	69.0	426	0.469	0.71381
Skarvsnes					
A1	Garnet-biotite gneiss	108.2	218.0	1.437	0.72616
A2	Biotite-garnet gneiss	43.69	271.2	0.4666	0.72044
A3	Biotite-garnet gneiss	102.9	182.9	1.629	0.73466
A4	Garnet-orthopyroxene-biotite granulite	64.78	333.1	0.5631	0.70968
A5	Garnet-orthopyroxene-biotite gneiss	73.51	187.0	1.138	0.73073
2601	Garnet-two-pyroxene-biotite granulite	43.89	337.4	0.3768	0.70739
2602	Garnet quartzofeldspathic gneiss	186.9	176.6	3.065	0.74735
2702	Garnet quartzofeldspathic gneiss	133.2	152.5	2.528	0.75445
Sinnan Rocks					
15	Biotite amphibolite	16.8	1050	0.046	0.70452
52	Biotite granite	58.9	177	0.964	0.71503
57	Migmatitic garnet-biotite gneiss	48.3	370	0.378	0.70879
59	Migmatitic biotite gneiss	44.1	559	0.228	0.70812
78	Migmatitic biotite gneiss	77.14	177.3	1.260	0.71800
Yamato Mountains					
A100	Clinopyroxene-quartz monzonite	143	2200	0.188	0.70897
A107	Two-pyroxene biotite charnockite	65.7	2014	0.094	0.71004
					0.70997

Table 1 (continued).

Sample No.	Rock	Rb* (ppm)	Sr* (ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$
A108	Two-pyroxene biotite gneiss	153	1120	0.396	0.71288
A119	Biotite gneiss	204	258	2.29	0.72928
A120C	Two-pyroxene-hornblende-biotite gneiss	38.5	224	0.497	0.71154
A506	Two-pyroxene biotite gneiss	129.3	766.3	0.4887	0.70922
A512	Two-pyroxene biotite gneiss	80.3	693	0.336	0.71125
A529	Orthopyroxene-biotite gneiss	145.2	218.9	1.921	0.72895
A530	Orthopyroxene-biotite gneiss	142	307	1.34	0.72192
A548A	Two-pyroxene biotite gneiss	68.1	874	0.226	0.70949
Y80A34A	Two-pyroxene biotite syenite	256	897	0.826	0.71364

* 4-digit value by isotope dilution, 3-digit value by X-ray fluorescence.

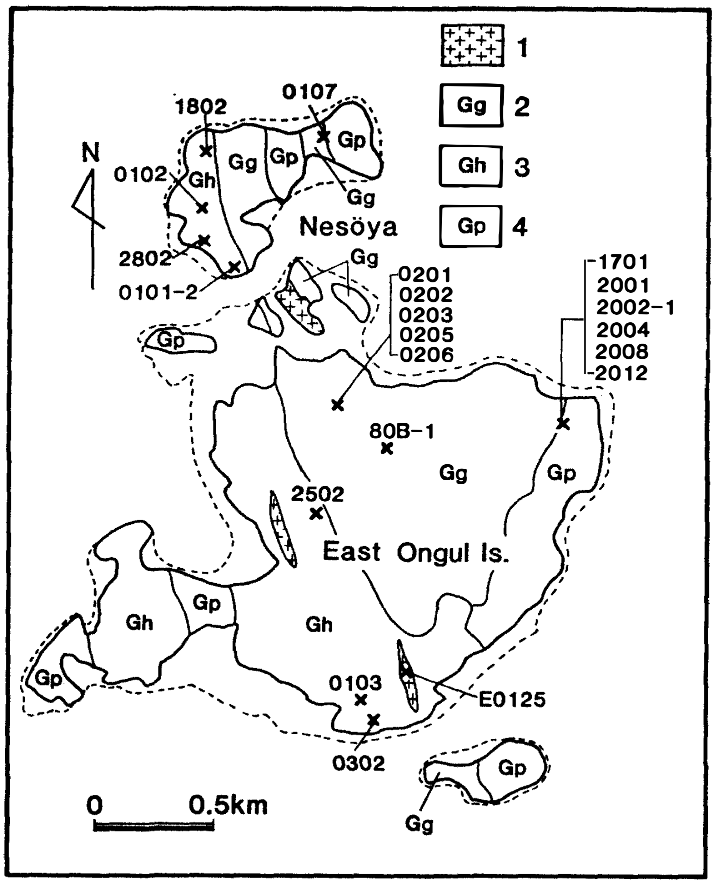

Fig. 2. Geological sketch map of East Ongul Island and Nesöya in the Ongul Islands, showing the localities of the investigated samples. Geological map is simplified from YANAI *et al. (1974). 1: Gneissose granite. 2: Garnet gneiss. 3: Hornblende gneiss. 4: Pyroxene gneiss.*

Sample 2012 is aplitic gneiss and may be younger than other samples, as it plots below the isochron. Sample 0103 plots above the isochron, although it is a hornblende gneiss typical in this area.

Samples 0201 to 0203 and 0205, which come from a single outcrop, give an age

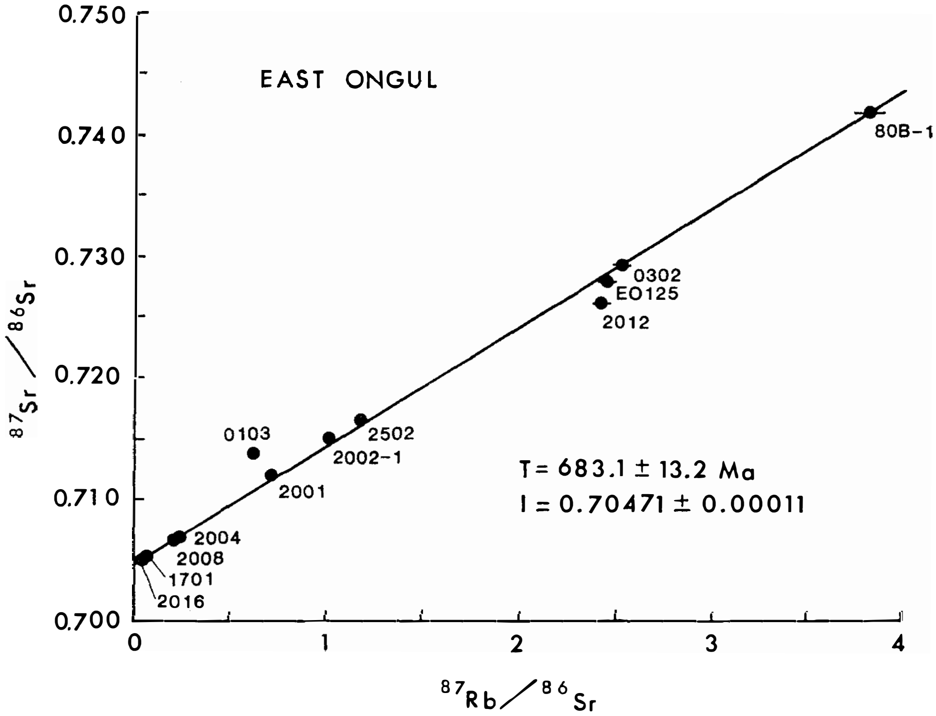

Fig. 3. Rb-Sr isochron plot for metamorphic rocks from East Ongul Island.

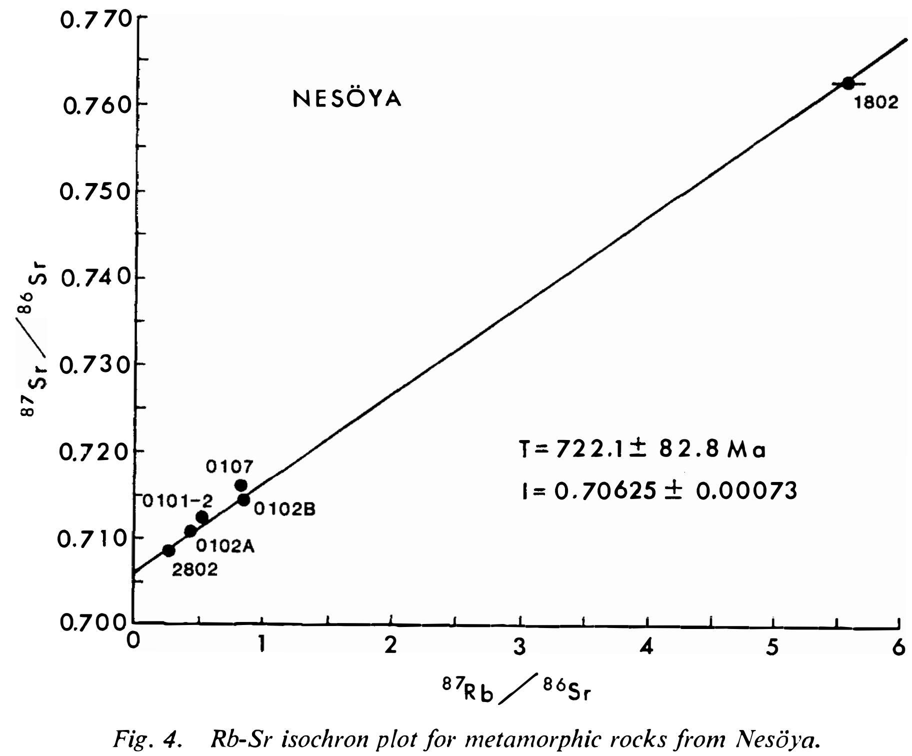

Fig. 4. Rb-Sr isochron plot for metamorphic rocks from Nesöya.

of 574±128 Ma and an initial ratio of 0.7050±0.003 with an MSWD of 3.2 (not plotted on Fig. 3). Inclusion of 0206 will result in a much larger MSWD of 9.7. The younger age may reflect the Sr isotopic redistribution in a later event, although a large scatter of data points makes it difficult to closely define the time of this event. Sample EO125 gave a K-feldspar-plagioclase-whole-rock isochron age of 482.5±9.5 Ma (SHIBATA *et al.*, 1985).

4.2. Nesöya

Nesöya is a small island situated to the north of East Ongul Island, of which the geology can be extended to Nesöya (Fig. 2). Samples are from an area about 0.5×0.5 km wide, and five of the six samples are from the nearly same horizon. The data points are plotted in Fig. 4. Four samples give an isochron age of 722.1±82.8 Ma with an initial ratio of 0.70625±0.00073. Two samples (0101-2 and 0107) lie above the isochron and are omitted from the calculation. The data points still show a large scatter (MSWD=9.4), and the line is not a true isochron but an errorchron.

On the other hand, one granitic pegmatite from West Ongul Island (68-2008) which was analyzed for comparison plots far above the isochron of East Ongul Island or Nesöya.

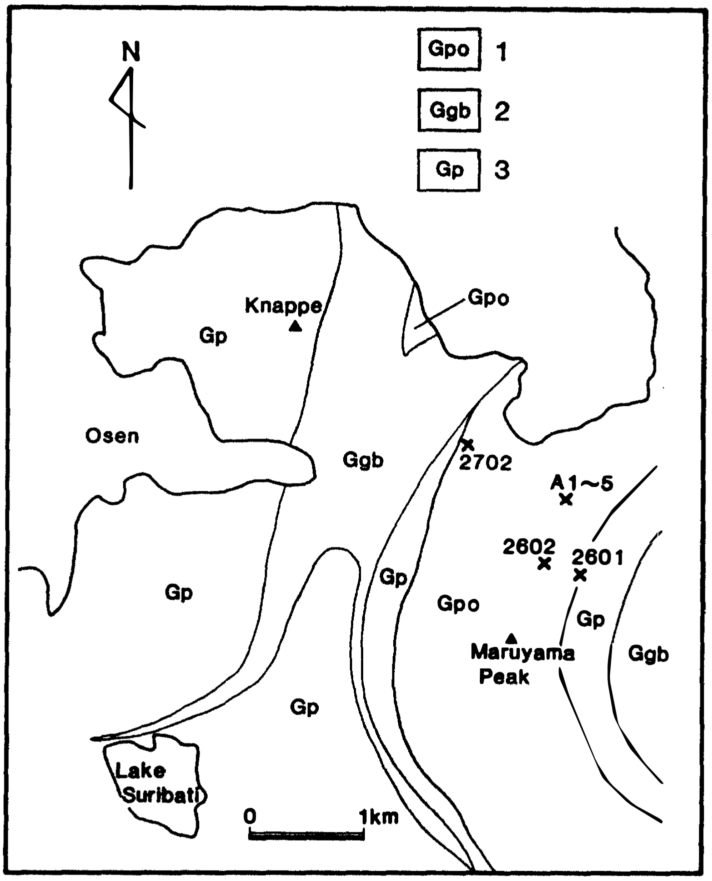

Fig. 5. Geological sketch map of a part of Skarvsnes in the Lützow-Holm Bay region, showing the localities of the investigated samples. Geological map is simplified from ISHIKAWA et al. (1977). 1: K-feldspar porphyloblastic gneiss. 2: Garnet-biotite gneiss. 3: Pyroxene gneiss.

4.3. *Skarvsnes*

Although eight samples were taken from a rather limited area within the same geological unit (Fig. 5), the data points scatter widely as shown in Fig. 6. Samples A2, A5 and 2702 define an isochron age of 1131±81 Ma with an initial ratio of 0.71280± 0.00094 (MSWD=2.5). Samples 2601, 2602 and A4 give an errorchron of 1033±90 Ma with an initial ratio of 0.70165±0.00079 (MSWD=3.6). Samples A1 to A5 are from

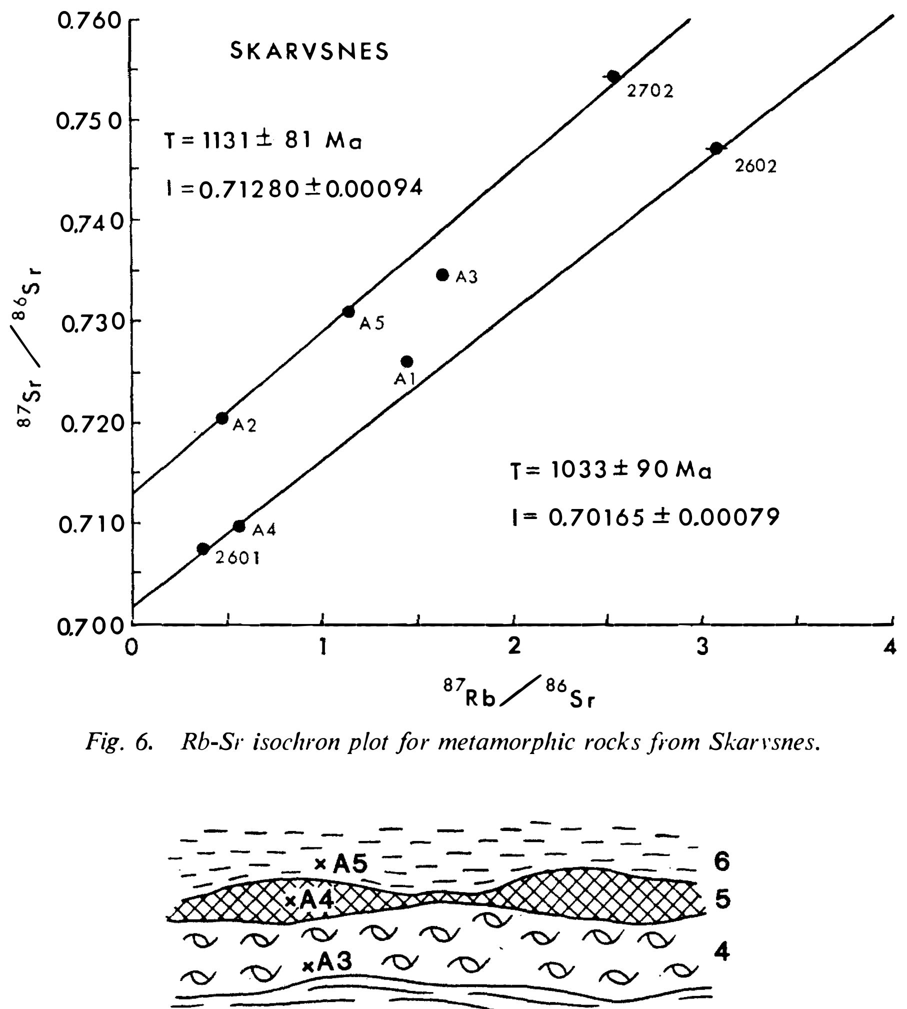

Fig. 6. Rb-Sr isochron plot for metamorphic rocks from Skarvsnes.

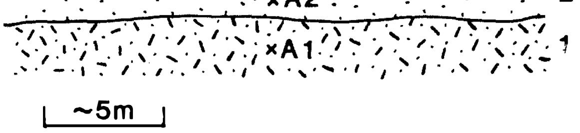

Fig. 7. Schematic sketch of the outcrop A1–5 in Skarvsnes. 1: Mesocratic garnet-biotite gneiss. 2: Leucocratic biotite-garnet gneiss. 3: Banded garnet-biotite gneiss. 4: K-feldspar porphyroblastic biotite-garnet gneiss. 5: Melanocratic garnet-orthopyroxene-biotite gneiss. 6: Mesocratic garnet-orthopyroxene-biotite gneiss.

a single outcrop 20 m in size and they may be considered as slab samples (Fig. 7). Adjacent samples, Al–A2 and A3–A5, give isochrons of 561 and 414 Ma, respectively. Sample A5 gave a biotite-K-feldspar-plagioclase-whole-rock isochron age of 468.9 ± 7.8 Ma (SHIBATA *et al.*, 1985). These younger ages indicate that the whole-rock isotopic system of samples Al to A5 was locally reset by a thermal event at around 500 Ma. SHIRAHATA (1983) reported a Rb-Sr whole-rock isochron age of 1180 Ma for two gneisses from Skarvsnes. Therefore, the whole-rock ages indicate an event at about 1100 Ma in the Skarvsnes district.

MAEGOYA *et al.* (1968) reported a Rb-Sr isochron age of 1090 ± 108 Ma for K-feldspars of gneisses from the Lützow-Holm Bay region including one sample from Skarvsnes. Although this age is apparently equal to the Rb-Sr whole-rock ages, a K-feldspar isochron does not necessarily give a real age indicative of any event, because the complete Sr isotopic homogenization occurred among minerals of metamorphic rocks in Skarvsnes (SHIBATA *et al.*, 1985). In addition, an evidence was found that a K-feldspar point plots to the lower left of a whole-rock point on a mineral isochron, giving an apparently older model age than a whole-rock one.

4.4. Sinnan Rocks

Sinnan Rocks is about 250 km away from Syowa Station, and only 50 km from Molodezhnaya Station (Fig. 1), where Rb-Sr whole-rock ages over 2000 Ma were reported (GREW, 1978). The region is largely occupied by migmatitic rocks of anatectic

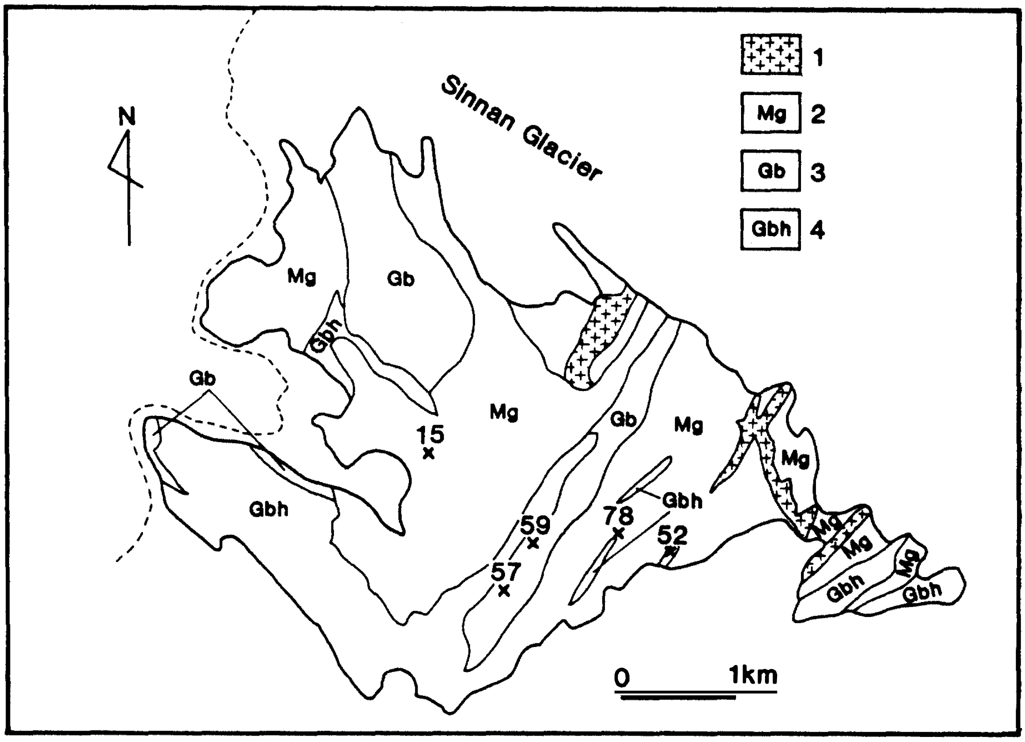

Fig. 8. Geological sketch map of Sinnan Rocks in the Prince Olav Coast, showing the localities of the investigated samples. Geological map is simplified from HIROI et al. (1983c). 1: Pink granite. 2: Granitic migmatite. 3: Biotite gneisses. 4: Biotite-hornblende gneisses.

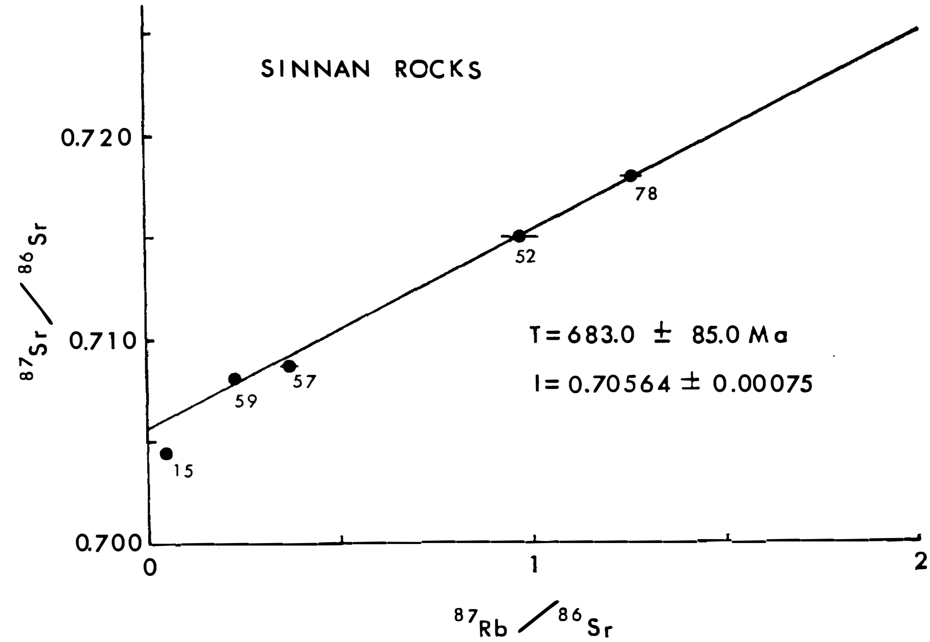

Fig. 9. Rb-Sr isochron plot for metamorphic rocks from Sinnan Rocks.

origin (HIROI *et al.*, 1983c). Samples are from three different lithological units (Fig. 8). However, all these samples show migmatitic appearance in common. Of five samples analyzed, four define an age of 683.0±85.0 Ma with an initial ratio of 0.70564±0.00075 and an MSWD of 4.7 (Fig. 9). An amphibolite sample (15) plots far below the isochron and is omitted from the calculation.

4.5. *Yamato Mountains*

The samples were taken from various parts of Massif-A in the Yamato Mountains (Fig. 10).

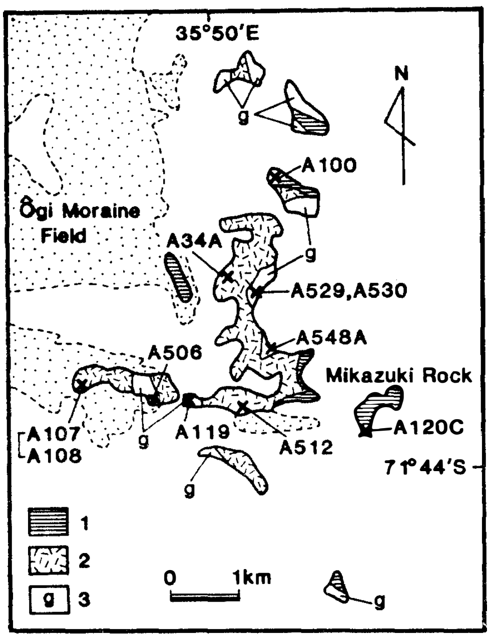

Fig. 10. Geological sketch map of Massif-A in the Yamato Mountains, showing the localities of the investigated samples. Geological map is simplified from SHIRAISHI et al. (1982). 1: Quartz monzonite. 2: Charnockitic syenite. 3: Orthopyroxene gneiss and calc-silicate gneiss.

The data points scatter widely, and do not constitute a single isochron. The samples are therefore grouped into two; four (A107, A108, A529, A530) and five (A100, A119, A120C, A512, A548A) samples define isochrons of 718.4±33.7 Ma and 696±165 Ma with initial ratios of 0.70899±0.00026 and 0.70725±0.00078, respectively (Fig. 11). Two samples (A506 and A34A), which lie far below the lower line, are omitted from the calculation. The MSWD for the upper isochron is 1.2, whereas that for the lower one is 6.4, thus the latter one is an errorchron. The samples defining the upper isochron are from small masses of over 100 m in diameter although two localities are 3 km apart from each other; their isochron age is relatively well defined. The samples giving the errorchron are from widely scattered localities (Fig. 10), and they occur closely associated with the quartz monzonite which intruded at the latest stage in the region. Therefore, these lines of evidence may be the cause of scattered data points. Interesting enough, however, the two whole-rock ages for the Yamato Mountains are similar to those for the Ongul Islands district, and they altogether demonstrate that an event of regional scale took place at about 700 Ma in eastern Queen Maud Land. Also noted is the higher initial ratios of rocks in the Yamato Mountains. Sample A529 gave a biotite-K-feldspar-plagioclase-whole-rock isochron age of 493.3±4.5 Ma (SHIBATA *et al.*, 1985).

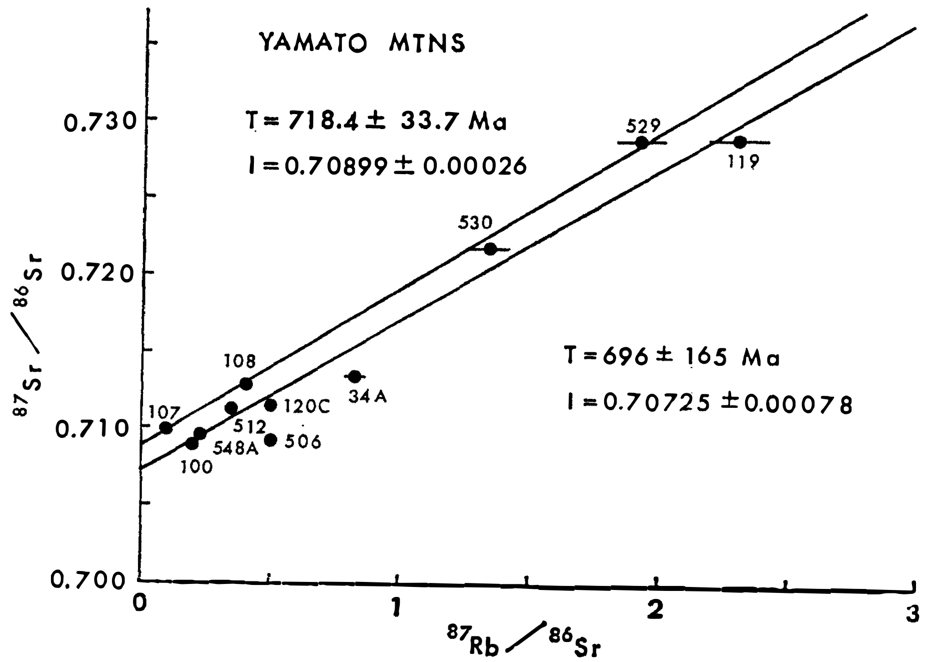

Fig. 11. Rb-Sr isochron plot for metamorphic rocks from the Yamato Mountains.

5. Discussion

Rb-Sr isochron ages for metamorphic rocks from eastern Queen Maud Land are summarized in Table 2. Some of the isochrons have MSWD's higher than 2.5, indicating the scatter of data points exceeding the limit of experimental error. This means some samples are of different origin or their Rb-Sr whole-rock systems were partly

Table 2. Rb-Sr whole-rock isochrons for metamorphic rocks from eastern Queen Maud Land.

Locality	N	Age (Ma)	Initial ratio	MSWD
East Ongul Island	10	683.1±13.2	0.70471±0.00011	0.80
Nesöya	4	722.1±82.8	0.70625±0.00073	9.37
Skarvsnes 1	3	1131 ±81	0.71280±0.00094	2.54
Skarvsnes 2	3	1033 ±90	0.70165±0.00079	3.59
Sinnan Rocks	4	683.0±85.0	0.70564±0.00075	4.72
Yamato Mts 1	4	718.4±33.7	0.70899±0.00026	1.21
Yamato Mts 2	5	696 ±165	0.70725±0.00078	6.40

opened. Nevertheless, Rb-Sr whole-rock ages concentrate at about 700 Ma, with the exception of the 1100 Ma ages for Skarvsnes.

No geological event at about 700 Ma has been postulated yet in eastern Queen Maud Land. The maximum temperature for the metamorphism in this district is estimated to be about 700°C or higher (ASAMI and SHIRAISHI, 1983; HIROI *et al.*, 1983b). Under this condition, the Rb-Sr whole-rock isotopic system of the metamorphic rocks is supposed to have been extensively affected and at least partly homogenized. The closure temperature for the Rb-Sr whole-rock system is estimated to be 650–700°C (HARRISON *et al.*, 1979). In addition, it was demonstrated on the Napier Complex of Enderby Land, that the Rb-Sr and even Sm-Nd whole-rock systems were locally re-equilibrated during the granulite-facies metamorphism at about 3100 Ma (MCCULLOCH and BLACK, 1984). Therefore, the Rb-Sr whole-rock ages of about 700 Ma obtained in this study are interpreted to represent the time of high-grade metamorphism, which must have been of regional scale involving the whole eastern Queen Maud Land, as the rocks from the Prince Olav Coast, Lützow-Holm Bay region, and Yamato Mountains recorded the 700 Ma ages.

The difference in crustal evolution between these areas are reflected in the initial $^{87}Sr/^{86}Sr$ ratios. Rocks from the Prince Olav Coast and Lützow-Holm Bay region give the initial ratios slightly lower than those of the Yamato Mountains. This may suggest the relatively younger age for the protolith of the Lützow-Holm Complex than that of the Yamato-Belgica Complex. Within the Yamato Mountains, however, there seems to be a variation in the initial $^{87}Sr/^{86}Sr$ ratio (Table 2). The difference in the initial ratio is also noticed on rocks around Syowa Station, *i.e.*, the initial ratio for rocks of East Ongul Island is lower than that of Nesöya. Presumably Sr isotopic homogenization occurred on local scale.

The metamorphic grade of the Prince Olav Coast to Lützow-Holm Bay region increases gradually southwestward from the amphibolite-facies to the granulite-facies (HIROI *et al.*, 1983b; MOTOYOSHI, 1986). The Rb-Sr whole-rock age of 683.0±85.0 Ma on the amphibolite-facies Sinnan Rocks, which is in the easternmost part of the Lützow-Holm Complex, is similar to those on the granulite-facies rocks of Syowa Station and the Yamato Mountains. On the other hand, charnockitic gneisses of the Rayner Complex at Molodezhnaya Station, which is located about 50 km to the east of Sinnan Rocks, yielded a Rb-Sr whole-rock age of 1020±60 Ma with an initial $^{87}Sr/^{86}Sr$ ratio of 0.7109±0.0015 (GREW, 1978). The age is older and the initial ratio higher than that of Sinnan Rocks; therefore, the metamorphic history of the Lützow-Holm and

Rayner Complexes is different, and the boundary of the two complexes should be somewhere to the east of Sinnan Rocks.

The Rb-Sr whole-rock ages on rocks from Skarvsnes are about 1100 Ma and definitely older than the 700 Ma ages discussed above. In addition, one set of the whole-rock samples from Skarvsnes gives the highest initial $^{87}Sr/^{86}Sr$ ratio among the samples dated in this study (Table 2). This means that some of the metamorphic rocks from Skarvsnes have still older crustal history. SHIRAHATA (1983) reported a Pb-Pb age of 1900 Ma for pyroxene gneisses from Skarvsnes, and this may represent the age of the protolith. SHIRAHATA (1983) further reported a Rb-Sr whole-rock age of 1180 Ma with two garnet gneisses. Taken together, the 1100 Ma ages from Skarvsnes are also interpreted to indicate the time of the high-grade metamorphism. Recently, TANAKA *et al.* (1985) reported a Sm-Nd isochron age of 895 ± 107 Ma with initial $^{143}Nd/^{144}Nd$ ratio of 0.51157 ± 0.00009 for three metamorphic rocks from the locality between A1 and 2602. They considered that the age represents the formation age of source rocks. However, this Sm-Nd age could also be a metamorphic age as shown by MCCULLOCH and BLACK (1984).

There seems to be no isotopic evidence for the 700 Ma event in Skarvsnes, although minerals and slab samples give younger ages of about 500 Ma. However, it contradicts petrological and structural evidence of the gradual increase of metamorphic grade from northeast to southwest through Skarvsnes in the Sôya Coast (HIROI *et al.*, 1983b: MOTOYOSHI, 1986), and of three stages of deformation throughout the Sôya Coast including Skarvsnes (ISHIKAWA, 1976; YOSHIDA, 1978). At present, it is not known why the Skarvsnes area does not indicate the 700 Ma metamorphism that affected the whole eastern Queen Maud Land. There might be another part of the older crust yet to be found within this district. Further isotopic study, especially by the Sm-Nd method, is needed to solve this problem.

6. Summary

The Lützow-Holm Complex in the Prince Olav Coast and Lützow-Holm Bay region and the Yamato-Belgica Complex in the Yamato Mountains both gave Rb-Sr whole-rock ages of about 700 Ma, which represent the time of the amphibolite- to granulite-facies metamorphism that affected the whole eastern Queen Maud Land. Within this district, however, rocks from Skarvsnes were subjected to metamorphism of about 1100 Ma, but not of 700 Ma.

The initial $^{87}Sr/^{86}Sr$ ratios of metamorphic rocks in eastern Queen Maud Land indicate a considerable variation on both regional and local scales, suggesting the difference in the age of protolith.

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Appendix

Table A-1. Original field numbers and constituent minerals of the samples.

Sample No.	Field No.	Constituent minerals									Others
		Qz	Pl	Kf	Bi	Hb	Op	Cp	Gt	Opq	
East Ongul Island											
1701	79021701		+		+						Sc, Cc*
2001	79022001	+	+	+	+	+	+			+	Zr, Mus*, Cc*
2002-1	79022002-1	+	+	+	+	+	+	+	+	−	Ap, Cc*, Ana*
2004	79022004#		+		+	+					Ap, Zr, Cc*, Chl*, Mus*
2008	79022008		+		+	+	+	+		−	Cc*
2012	79022012	+	+	+	−				+	−	Zr
2016	79022016		+		+	+	+	+	+	+	Ap, Cc*
EO125	80EO125#	+	+	+	−	+				+	Sph, Mus*, Cc*
80B-1	80B-1	+	+	+	+	−	+		+	+	Ap, Zr, Rt, Mus*, Cc*
0103	79030103	+	+	+	+	+				+	Ap, Mus*
0302	73070302	+	+	+	−	+				+	Zr, Ap
2502	83122502	+	+	+	+	+				+	Zr, Ap, Mus*
0201	79100201					−	+			+	Cc*
0202	79100202		+		+	+	+			−	Ap
0203	79100203		+		+						Ap, Chl*
0205	79100205		+		−	+	+	−	+		Cc*
0206	79100206		+		+	+				−	Ap, Cc, Tre*

Table A-1 (continued).

Sample No.	Field No.	Constituent minerals									Others
		Qz	Pl	Kf	Bi	Hb	Op	Cp	Gt	Opq	
Nesöya											
0101-2	73070101-2	+	+	+	+	+				+	Ap, Cc*, Chl*
0102A	73070102A	+	+	+	+	+				+	Ap, Cc*
0102B	73070102B	+	+	+	+						Zr
0107	73070107	+	+	+	+					+	Ap, Zr
1802	79021802	+	+	+	+				+	+	Ap
2802	84122802	+	+	+	+	+				+	Ap
West Ongul Island											
68-2008	68022008	+	+	+	+					+	
Skarvsnes											
A1	840126A1	+	+	+	+				+	+	Rt, Ap
A2	840126A2	+	+	+	+				+	+	Rt, Ap, Zr
A3	840126A3	+	+	+	+				+	+	Rt, Ap, Zr
A4	840126A4		+	A	+		+		+	+	Ap, Zr
A5	840126A5#	+	+	+	+		+		+	+	Ap, Zr, Chl*
2601	84012601		+		+		+	+	+	+	Ap
2602	84012602	+	+	+	+				+	+	Ap, Cc*
2702	84012702	+	+	+					+	+	Zr
Sinnan Rocks											
15	81S15	+	+		+	+				+	Sph, Ap, Zr, Cc*, Chl*
52	81S52	+	+	+	+					+	Ap, Zr, Mus*, Chl*
57	81S57	+	+		+				+	+	Ap, Rt, Zr
59	81S59	+	+	+	+	—				+	Ap, Sph, Ort, Chl*
78	81S78	+	+	+	+					+	Ap, Zr
Massif A, Yamato Mountains											
A34A	Y80A34A	+	+	+	+		+	+		+	Ap, Zr, Cc*
A100	Y80A100	+	+	+	+	—		+		+	Sph, Ap
A107	Y80A107	+	+	+	+		+	+		+	Ap, Ort, Zr, Cc*
A108	Y80A108	+	+	+	+	—	+	+		+	Ap, Zr
A119	Y80A119	+	+	+	+					+	Grap, Zr
A120C	Y80A120C#	+	+		+	+	+	+		+	Ap, Zr
A506	Y80A506	+	+	+	+		+	+		+	Ap, Zr
A512	Y80A512	+	+	+	+	+	+	+		+	Ap, Zr
A529	Y80A529#	+	+	+	+		+			+	Ap, Zr, Chl*, Mus*, Cc*
A530	Y80A530	+	+	+	+		+			+	Ap, Zr, Chl*, Mus*, Cc*
A548A	Y80A548A	+	+	+	+		+	+		+	Ap, Zr, Cc*

+: present, —: trace, *: retrogressive, A: present as antiperthite #: described in SHIBATA *et al.* (1985)

Mineral abbreviations

Ana: anatase, Ap: apatite, Bi: biotite, Cc: carbonate mineral(s), Chl: chlorite, Cp: clinopyroxene, Grap: graphite, Gt: garnet, Hb: hornblende, Kf: K-feldspar, Mus: muscovite, Op: orthopyroxene, Opq: opaque mineral(s), Ort: orthite, Pl: plagioclase, Qz: quartz, Rt: rutile, Sc: scapolite, Sph: sphene, Tre: tremolite, Zr: zircon.