Proc. NIPR Symp. Antarct. Geosci., **10**, 92–101, 1997

PRELIMINARY RESULT FOR THE Nd AND Sr ISOTOPE CHARACTERISTICS OF THE ARCHAEAN GNEISSES FROM MOUNT PARDOE, NAPIER COMPLEX, EAST ANTARCTICA

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Abstract: A Sm-Nd whole-rock isochron for five mafic gneisses at Mount Pardoe defines an age of 2595±262 Ma with an initial $^{143}Nd/^{144}Nd$ ratio of 0.50937 ± 0.00024, which corresponds to an initial ε Nd value at that time +1.9. The initial ε Nd values for the felsic gneisses of the Mount Pardoe and Tonagh Island are –3.5 (–3.0 ~ –6.4) and –9.5 (–9.2 ~ –9.8), respectively which are low compared with that of CHUR (Chondritic Uniform Reservoir). This suggests that these rocks had a long crustal history before *ca.* 2500 Ma. The Sm-Nd ages obtained from the whole-rock samples do not represent the primary age, but correspond to the D_3-M_3 tectonothermal event. The difference in initial ε Nd value for the mafic gneisses of Mount Pardoe and Tonagh Island may reflect the different chemical compositions of the protolith.

In the Rb-Sr whole-rock isochron diagram, the felsic gneisses at Mount Pardoe yield an age of 2919±233 Ma with an initial $^{87}Sr/^{86}Sr$ ratio of 0.70581±0.00027. Mafic gneisses at Mount Pardoe give an Rb-Sr whole-rock isochron age of 2908±216 Ma with an initial $^{87}Sr/^{86}Sr$ ratio of 0.70517±0.00098.

key words: Napier Complex, geochronology, mafic gneiss, Sm-Nd age, Mount Pardoe

1. Introduction

The Napier Complex is one of the oldest portions of continental crust in East Antarctica. This complex consists of high-temperature granulite-facies rocks which are characterized by sapphirine-quartz, orthopyroxene-sillimanite-quartz and osumilite-bearing mineral assemblages (SHERATON *et al.*, 1987). Extremely old ages of nearly 4000 Ma have been reported for some orthogneiss (BLACK *et al.*, 1986a). The Napier Complex underwent three episodes of deformation in the late Archaean (HARLEY and BLACK, 1987; MCCULLOCH and BLACK, 1984). D_1-M_1 occurred at about 3070 Ma (JAMES and BLACK, 1981). High-grade granulite-facies condition of 900°C and 9–11 kbar were reached at that time (SHERATON *et al.*, 1987). D_2-M_2 is chronologically poorly constrained but might have occurred at about 2900 Ma (SHERATON *et al.*, 1987). D_3-M_3 occurred under transitional amphibolite to granulite-facies conditions (about 650°C and 7 kbar) at about 2450 Ma (BLACK and MCCULLOCH, 1987). Mount Pardoe is situated in the southern part of the Amundsen Bay area (Fig. 1), which belongs to the highest grade portion of the Napier Complex (HARLEY and HENSEN, 1990).

Felsic gneiss is the dominant rock type in the area. Other rock types are mainly

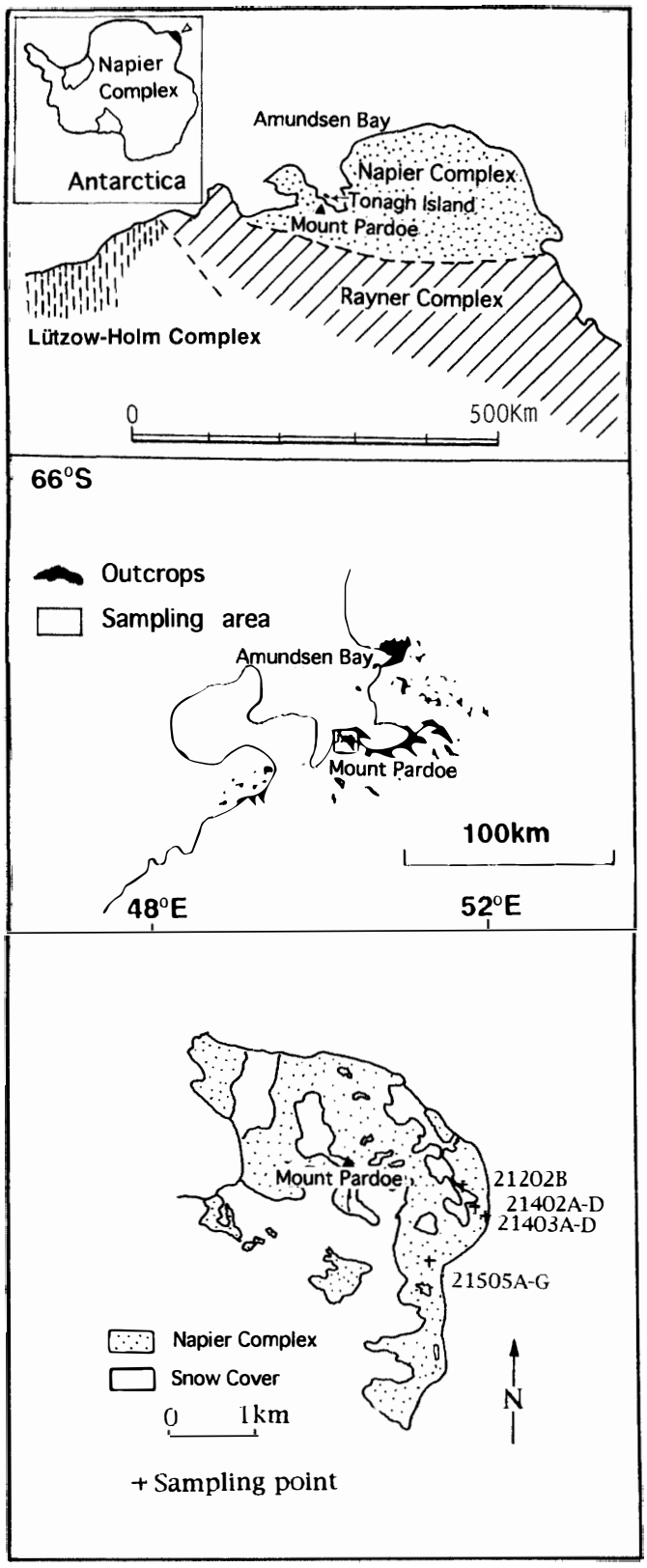

Fig. 1. Location map of Mount Pardoe and three metamorphic complexes (after SHIRAISHI *et al., 1995) with sampling site.*

mafic gneiss with subordinate garnet-quartz gneiss and ultramafic gneiss. The felsic and mafic gneisses are intimately interlayered. Felsic gneiss at Mount Pardoe gave an Sm-

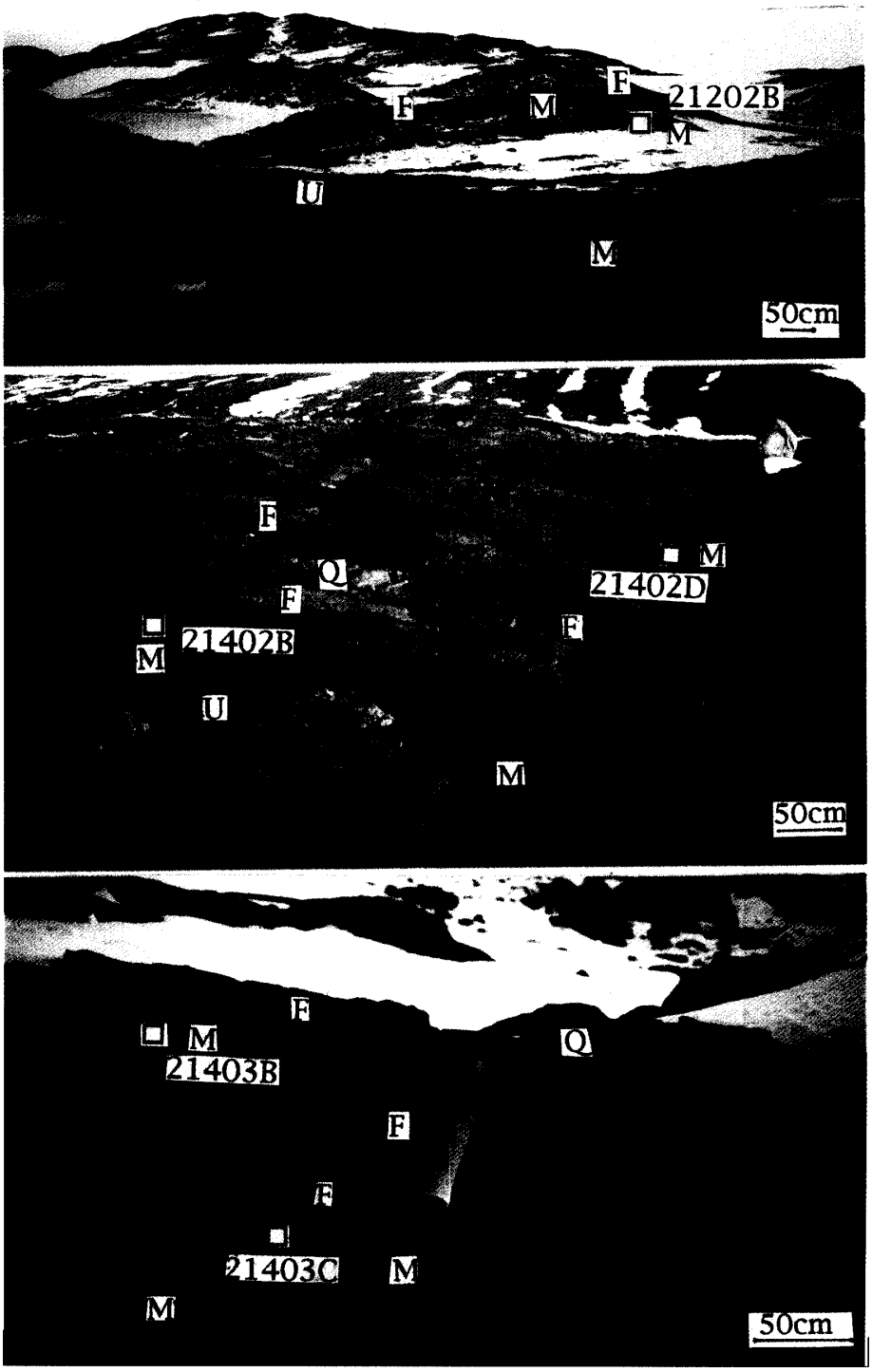

Fig. 2. Sampling points of the mafic gneiss for the whole-rock samples. Open squares: sampling points; numbers: sampling numbers; M: mafic gneiss; F: felsic gneiss; Q: garnet-quartz gneiss; U: ultramafic gneiss.

Nd whole rock isochron age of 2516±274 Ma (TAINOSHO *et al.*, 1994). OWADA *et al.* (1994) reported an Sm-Nd age of 2458 ± 61 Ma for the felsic gneiss at Tonagh Island, which is situated 10 km north of Mount Pardoe. Similar Sm-Nd whole isochron ages (around 2450 Ma) have been obtained from elsewhere in the Napier Complex (SHERATON *et al.*, 1987). On the other hand, the mafic gneiss of Tonagh Island yields an isochron age of 3708±533 Ma (OWADA *et al.*, 1994).

We measured the whole-rock Sm-Nd and Rb-Sr isochron ages of the mafic gneisses from Mount Pardoe to estimate the time of the old mafic igneous activity and re-setting.

2. Samples

Mount Pardoe in the Napier Complex is underlaid mainly by felsic gneiss, mafic gneiss, garnet-quartz gneiss and ultramafic gneiss. Most felsic and mafic gneisses are massive and medium-grained, and have granoblastic-polygonal textures. Five mafic gneisses (21202B, 21402B, 21402D, 21403B and 21403C) were collected for Nd and Sr isotope measurements (Fig. 1). The mafic gneiss contains andesine antiperthite, orthopyroxene and clinopyroxene. The pyroxenes are partly replaced by fine-grained aggregates of biotite. The mafic gneiss is generally medium-grained and locally well-foliated (Fig. 2). Lenses of ultramafic gneiss occur in the mafic gneisses. They contain abundant orthopyroxene and clinopyroxene. The felsic gneiss is commonly interlayered with the mafic gneiss. Eight felsic gneisses were collected for Nd and Sr isotope measurements from one locality (21505A-G) at Mount Pardoe (Fig. 1). The felsic gneiss consists of mesoperthite, quartz and orthopyroxene. Mesoperthite has sometimes re-crystallized to plagioclase and K-feldspar.

3. Analytical Procedures

Sm, Nd, Rb and Sr concentrations were measured by the isotope dilution method. The $^{143}Nd/^{144}Nd$ and $^{87}Sr/^{86}Sr$ ratios were determined by MAT261 type mass spectrometer at the Institute for Study of the Earth's Interior, Okayama University. Mass spectro-

Table 1. Major elements of the mafic gneisses from Mount Pardoe.

	21202B	21402B	21402D	21403B	21403C
SiO_2	49.85	53.13	57.32	64.96	53.42
TiO_2	0.97	1.30	0.09	0.56	0.01
Al_2O_3	13.99	15.72	23.58	14.25	9.08
Fe_2O_3	14.27	13.02	2.76	6.75	8.18
MnO	0.18	0.17	0.03	0.05	0.52
MgO	8.78	8.41	1.79	2.91	9.04
CaO	10.36	6.35	9.47	3.13	19.39
Na_2O	1.78	1.84	2.60	3.19	0.49
K_2O	0.29	0.23	1.17	2.65	0.08
P_2O_5	0.09	0.10	0.02	0.14	0.10
Total	100.56	100.27	98.83	98.59	100.31

metric analyses follow the procedure of KAGAMI *et al.* (1995). All $^{143}Nd/^{144}Nd$ and $^{87}Sr/^{86}Sr$ ratios were normalized to $^{146}Nd/^{144}Nd=0.7219$ and $^{86}Sr/^{88}Sr=0.1194$. $^{143}Nd/^{144}Nd$ results are reported relative to $^{143}Nd/^{144}Nd=0.512640$ for BCR-1. Sr isotope ratios for NBS 987 were measured twice during this study, with a mean ratio of 0.710238 ± 0.000009 (2σ). We estimate an error of 0.1% for the Sm/Nd ratios of each sample based on reproducibility of the data. We used the following CHUR parameters for calculation of initial ε Nd values: $^{143}Nd/^{144}Nd(present)=0.512638$, $^{147}Sm/^{144}Nd$ (present)=0.1966, $\lambda^{147}Sm=6.54\times10^{-12}y^{-1}$, $^{87}Sr/^{86}Sr$ (present)=0.7045, $^{87}Rb/^{86}Sr$ (present)=0.0827, $\lambda^{87}Rb=1.42\times10^{-11}y^{-1}$.

Major element compositions of the mafic gneisses were determined by XRF at Kobe University. They are listed in Table 1.

4. Results

Analytical results are listed in Tables 2 and 3. Sm-Nd isotope data are plotted in Fig. 3. Five mafic gneisses from Mount Pardoe give an Sm-Nd isochron age of 2595± 262 Ma and an initial ratio of 0.50937±0.00024 (Fig. 3), which corresponds to an initial

Table 2. Sm-Nd isotopic analyses of the mafic gneisses from Mount Pardoe.

Mafic gneiss

Sample	Sm (ppm)	Nd (ppm)	$^{147}Sm/^{144}Nd$	$^{143}Nd/^{144}Nd$ (2σ)
21202B	3.60	11.5	0.191	0.512640±14
21402B	4.00	13.8	0.176	0.512406±16
21402D	1.60	11.8	0.082	0.510879±18
21403B	3.38	21.1	0.097	0.510973±18
21403C	4.81	25.1	0.116	0.511266±13

Table 3. Rb-Sr isotopic analyses of the felsic and mafic gneisses from Mount Pardoe.

Felsic gneiss

Sample	Rb (ppm)	Sr (ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$ (2σ)
21505B	29.2	96.6	0.897	0.742342±14
21505C	21.3	117.2	0.526	0.728107±13
21505D	59.2	48.3	3.592	0.850504±14
21505E	28.1	115.1	0.707	0.736653±12
21505F	45.2	56.9	2.321	0.804776±15

Mafic gneiss

Sample	Rb (ppm)	Sr (ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$ (2σ)
21402A	38.9	50.5	2.248	0.798435±14
21402B	1.5	82.5	0.054	0.706789±14
21402C	1.9	70.7	0.080	0.709125±14
21403D	1.5	399.3	0.592	0.730570±15

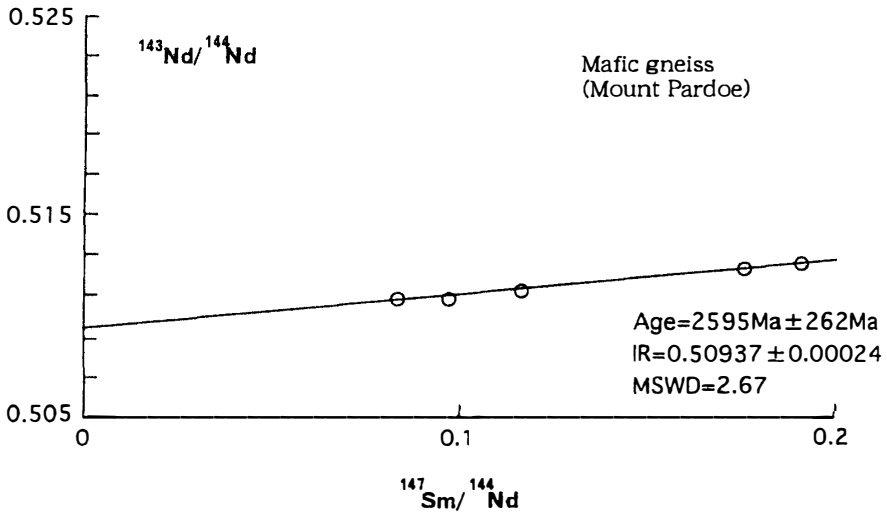

Fig. 3. Sm-Nd whole-rock isochron diagrams for the mafic gneisses from Mount Pardoe.

ε Nd of +1.9. However, if we extract two samples (21403B and 21403C) which show deformation texture, the Sm-Nd isochron for three samples defines an age of 2472±35 Ma and an initial ratio of 0.50938±0.00003. The felsic gneisses at Mount Pardoe yield an isochron age of 2561 Ma±274 Ma with an initial ratio of 0.50914±0.00021 (TAINOSHO *et al.*, 1994). The large uncertainties of the age and initial ratio are due to the limited ranges of $^{143}Nd/^{144}Nd$ and $^{147}Sm/^{144}Nd$ ratios for the samples. Initial ε Nd values at 2561 Ma of individual felsic gneisses range from –3.0 to –6.4.

Rb-Sr isotope analyses were done on the felsic and mafic gneisses from Mount Pardoe. These isotopic results are listed in Table 3. Whole-rock data for the felsic gneisses are plotted on an isochron diagram, but the data are slightly scattered (Fig. 4). Four felsic gneisses gave an age of 2919±233 Ma with an initial $^{87}Sr/^{86}Sr$ ratio of 0.70581±0.00027. Four mafic gneisses from Mount Pardoe give an isochron age of 2908±216 Ma and initial ratio of 0.70517±0.00098 (Fig. 4). All felsic and mafic gneisses yield an Rb-Sr isochron age of 2948±106 Ma and an initial ratio of 0.70518± 0.00070 (Fig. 4). The errors in the Rb-Sr isochron ages are larger than those of the Sm-Nd systems.

5. Discussion and Conclusions

The mafic gneisses at Mount Pardoe gave an Sm-Nd whole- rock age of 2595±262 Ma with an initial ratio of 0.50937. The felsic gneisses gave an Sm-Nd whole-rock age of 2561±274 Ma with an initial ratio of 0.50914 (TAINOSHO *et al.*, 1994). These ages are almost identical to the Sm-Nd whole-rock age of 2458±61 Ma with an initial ratio of 0.50897 for the felsic gneiss from Tonagh Island (OWADA *et al.*, 1994). These samples from Mount Pardoe show granuloblastic fabrics overprinted, so their isochron age probably reflect re-equilibration of the isotopic system on a whole-rock scale. Similar ages

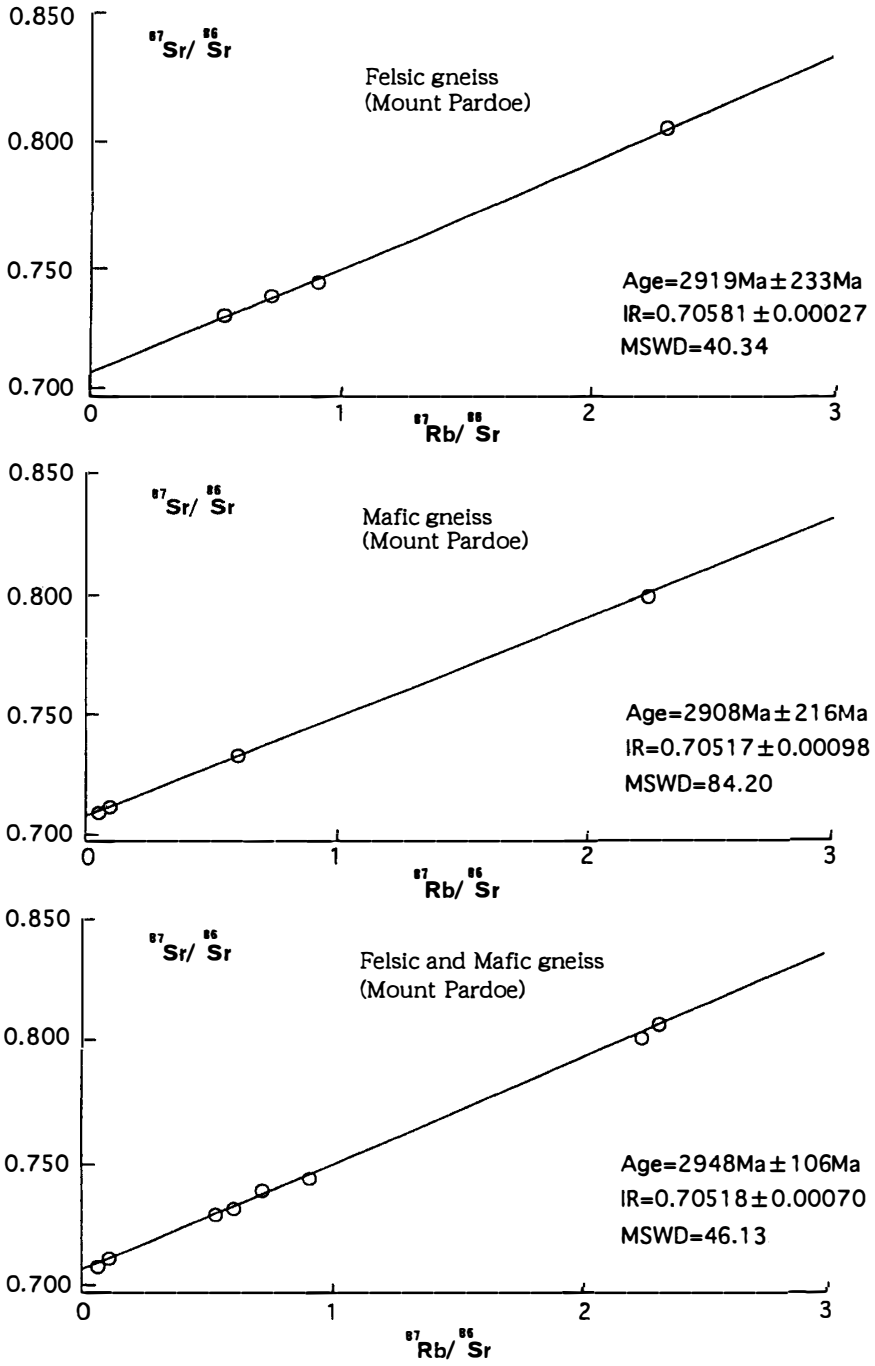

Fig. 4. Rb-Sr whole-rock isochron diagrams for the felsic and mafic gneisses from Mount Pardoe.

have also been reported from the Casy Bay–Fyfe Hills region (40 km west of Tonagh Island) (SHERATON *et al.*, 1987). Ages of about 2450 Ma have been obtained from many localities in the Napier Complex (SHERATON *et al.*, 1987). A tectonothermal event at about 2450 Ma seems to have been strong enough to cause re-equilibration of the Sm-Nd isotopic system. These Sm-Nd ages (about 2450 Ma) correspond to the D_3-M_3 tectonothermal event in the Napier Complex (SHERATON *et al.*, 1987). The Sm-Nd whole

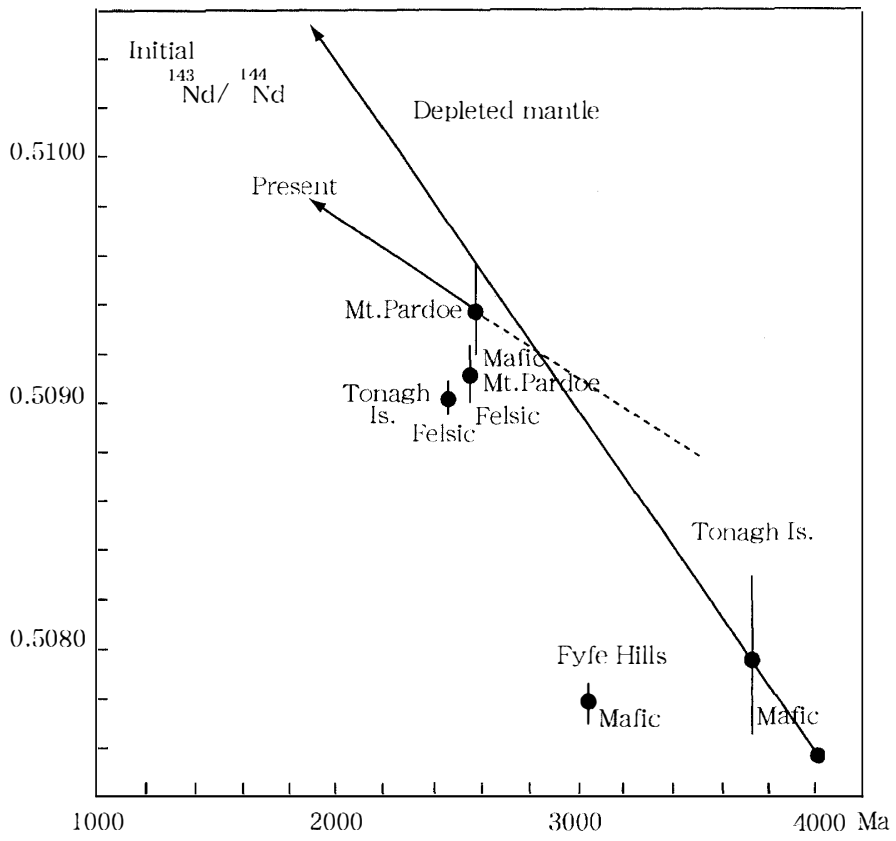

Fig. 5. Initial $^{143}Nd/^{144}Nd$ ratio vs. age diagram. Mafic: mafic gneiss; Felsic: felsic gneiss; solid line: error bar. Fyfe Hills: after Black *et al. (1983a), Tonagh Island: after* Owada *et al. (1994), felsic gneiss from Mount Pardoe: after* Tainosho *et al. (1994).*

rock isochron ages indicate a major period of re-equilibration. The initial $^{143}Nd/^{144}Nd$ ratio of the felsic gneiss of Mount Pardoe is similar to that of the felsic gneiss of Tonagh Island (Fig. 5). However initial ε Nd values for the both felsic gneisses are distinctly different from one another, that is, the values of the Mount Pardoe and Tonagh Island are –3.5 (–3.0 ~ –6.4; Tainosho *et al.*, 1994) and –9.5 (–9.2 ~ –9.8; Owada *et al.*, 1994), respectively. These initial ε Nd values are distinctly low compared with those of the mafic gneisses of Mount Pardoe (+1.9) and Tonagh Island (+2.6; Owada *et al.*, 1994). This result suggests that the mafic gneisses are derived from different source material compared with that of the felsic gneiss.

The initial ε Nd value (=–3.5) for the felsic gneisses from Mount Pardoe is extremely low compared with that of CHUR, suggesting that the felsic gneisses had a long crustal history before about 2450 Ma. Furthermore, the felsic gneisses of Mount Pardoe show T_{DM} model ages of 2970 to 3750 Ma, also consistent with derivation from much older felsic crust. The initial ratios of the Sm-Nd whole-rock isochron can provide constraints on the time of crust formation (McCulloch and Black, 1984).

The felsic gneiss at Mount Pardoe yields an Rb-Sr age of 2919±233 Ma with an

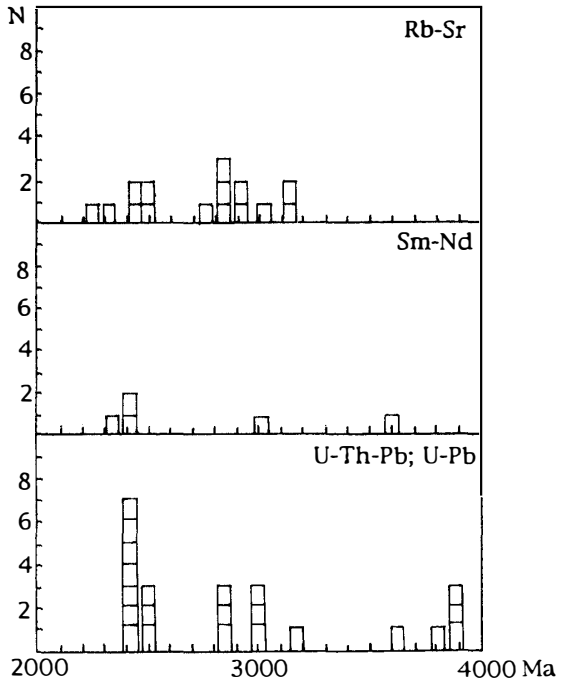

Fig. 6. Frequency of the isotopic age determinations for the metamorphic rocks in the Napier Complex. N is number of samples. Rb-Sr age, Sm-Nd age: whole-rock age; U- Th-Pb age: zircon age by ion microprobe; U-Pb: zircon age. Data sources for age are BLACK *and* JAMES *(1979, 1983);* BLACK *et al. (1983a, b, 1984, 1986a, b);* SHERATON *et al. (1987);* SHERATON *and* BLACK *(1981, 1983);* GREW *et al. (1982);* JAMES *and* BLACK *(1981);* COMPSTON *and* WILLIAMS *(1982),* MCCULLOCH *and* BLACK *(1984);* OWADA *et al. (1994);* TAINOSHO *et al. (1994).*

initial ratio of 0.70581. The mafic gneisses at Mount Pardoe give an age of 2908±216 Ma with an initial ratio of 0.70517. These data suggest that the Rb-Sr ages reflect isotopic resetting during a tectonothermal event.

It is very difficult to determine the age of the protoliths because of the effects of subsequent tectonothermal events on the isotopic systems. Figure 6 shows isotopic age determination from the whole area in the Napier Complex. Rb-Sr whole rock ages around 2500 Ma and 2900 Ma are reported from many localities in the Napier Complex.

Acknowledgments

We wish to thank Drs. K. SHIRAISHI, Y. OSANAI and N. TSUCHIYA for their helpful suggestions and discussions of the field occurrence and tectonics.

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(Received February 10, 1997; Revised manuscript accepted June 9, 1997)