Proc. NIPR Symp. Antarct. Geosci., 5, 75-83, 1991

PRELIMINARY NOTE ON PALEOINTENSITIES OF THE GEOMAGNETIC FIELD OBTAINED FROM ROCKS IN ANTARCTICA

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Abstract: Thellier's method was applied to the metamorphic and volcanic rocks of the Napier Complex in Enderby Land, Ongul Islands, Mawson Station, Sør Rondane Mountains and McMurdo Sound. The samples treated have partly ambiguous ages and sometimes show undesirable thermomagnetic properties which cause only a small linear portion in NRM-TRM diagrams and inconsistent paleointensity values for different specimens of the same sample.

However, results from Enderby Land, Sør Rondane and McMurdo Sound indicate that geomagnetic field strength was 20% higher in the period of 2.5 Ga to 500 Ma, 20% lower 500 Ma ago and 30% higher 1 Ma ago than today, respectively.

1. Introduction

Paleomagnetic intensity is important in understanding mechanism and history of the Earth's magnetic field. Summarized data by MERRILL and MCELHINNY (1983) and HALE (1987) show there would have been a sharp increase in Earth's magnetic field between 3.0 and 2.5 Ga ago, and a marked dip around 500 Ma ago. Many rock specimens have been collected by the Japanese Antarctic Research Expedition parties. In this study Thellier's method was applied to the samples of which ages were considered to be between 2.5 Ga and 500 Ma, 500 Ma and around 1 Ma.

2. Samples

The localities of samples are shown in Fig. 1. One pyroxene granulite and six mafic dykes were selected for our experiments from the Napier Complex, where BLACK and JAMES (1983) reported Rb-Sr ages of 2.3 Ga to 480 Ma for dykes and suggested the last metamorphic event of 2.5 Ga. Summarization of metamorphism and chronological data on Napier Complex was shortly reported by FUNAKI (1988). Seven hornblende gneisses were collected from East Ongul Island near Syowa Station. Natural remanent magnetization (NRM) of these samples was reported already by FUNAKI and WASILEWSKI (1986). Gneisses of East Ongul Island were dated from 560 to 387 Ma by K-Ar method (KANEOKA *et al.*, 1968; YANAI and UEDA, 1974) and from 726 to 465 Ma by Rb-Sr method (NICOLAYSEN *et al.*, 1961; MAEGOYA *et al.*, 1968). Three charnockites from Mawson Station having K-Ar age of 475 Ma (SAITO, private communication) were also studied.

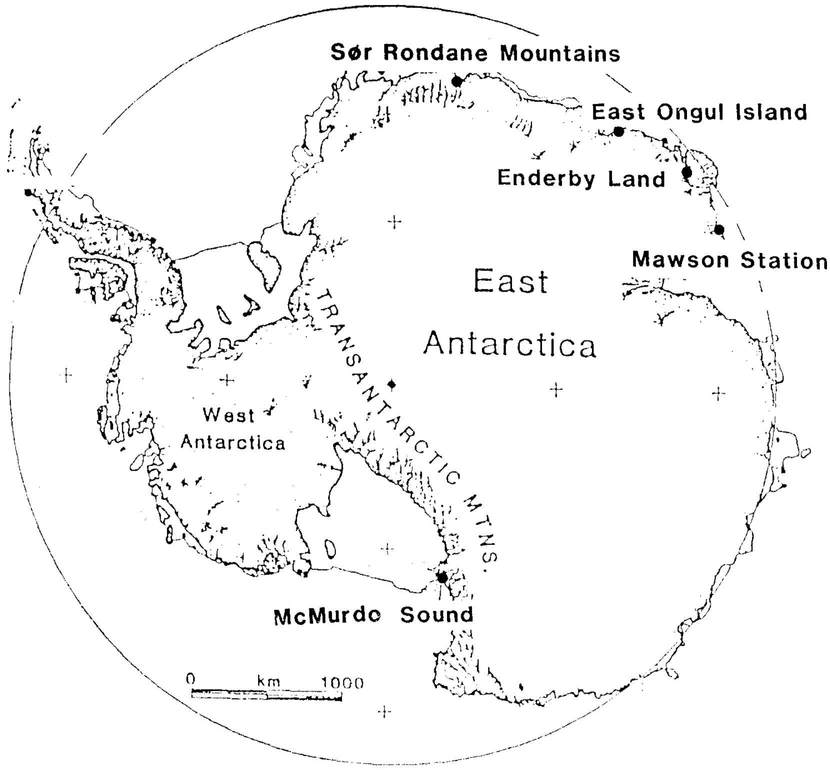

Fig. 1. Map of sampling site.

From the Sør Rondane Mountains, three syenite samples and two dolerite ones were analyzed. Of these samples, FUNAKI (1990) investigated the NRM and TAKIGAMI obtained a ^{40}Ar-^{39}Ar age of 500 Ma (private communication). We studied about seven young basaltic rocks near McMurdo Sound, ages of which range from 0.43 Ma to 2.9 Ma by K-Ar method (TREVES, 1967; FORBES *et al.*, 1974; KYLE and TREVES, 1974; ARMSTRONG, 1978). FUNAKI (1984) reported some magnetic properties of their NRMs, which help us to choose samples suitable for Thellier's method.

3. Analytical Method and Results

Thellier's method was used for analysis. Details of this method were given somewhere else (*e.g.*, SAKAI and FUNAKI, 1988). Thellier's method is based on proportionality of partial TRM to ambient magnetic field. Samples are treated in a series of a pair of heating-cooling cycles, repeated in zero and known field, with progressively increasing temperature. Vector calculus on magnetization measured after every cycle give NRMs demagnetized in zero field and TRMs acquired in known field. These data are analyzed in the diagram which plots the NRM on the ordinate and the TRM on the abscissa. The slope of a line, which is best fitted to the data points by the least squares method, indicates the ratio of the paleofield to the laboratory field. In this study nitrogen gas atmosphere was used over 200°C.

Examples of the analytical result of the Napier Complex are shown in Figs. 2 and 3. In Fig. 2, the data of granulite sample (1803) well defines a straight line in a low

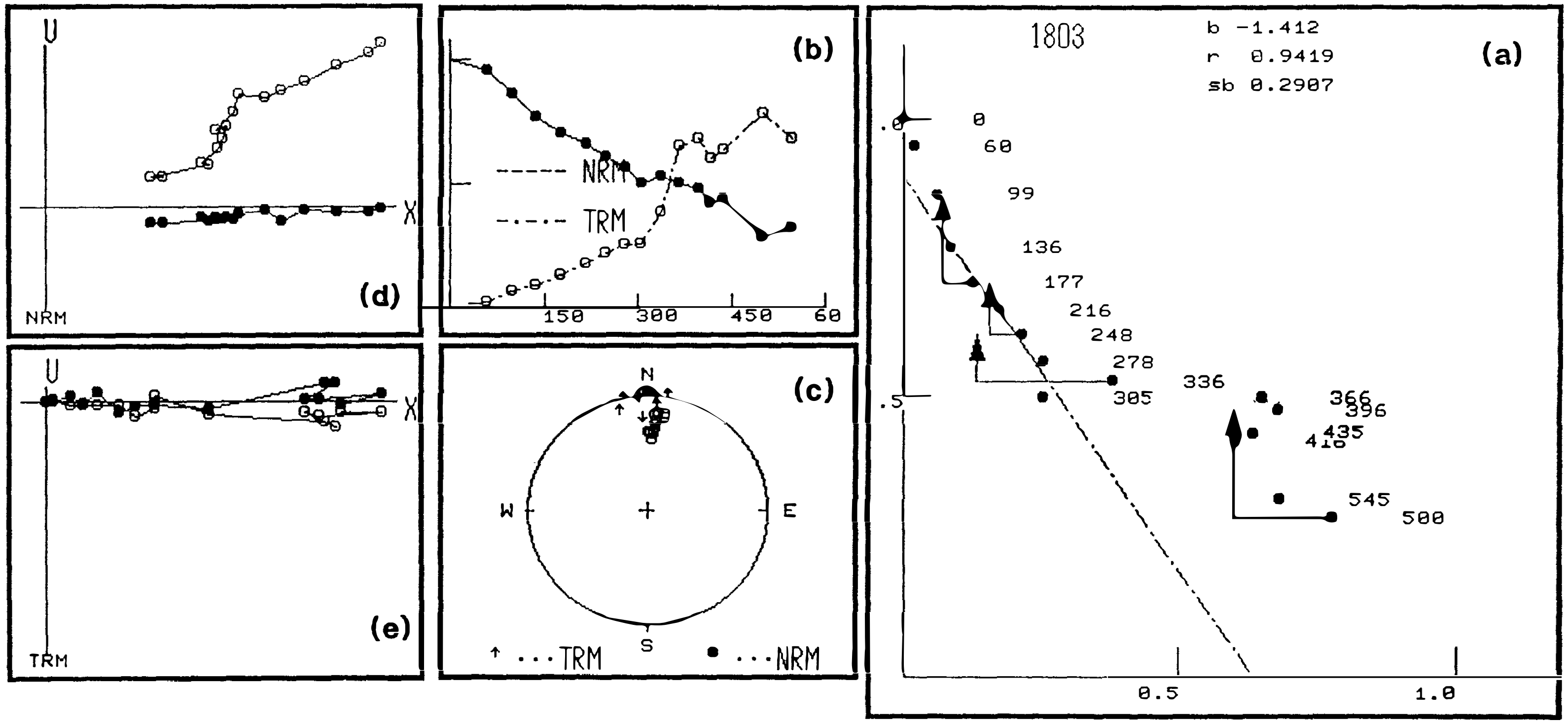

Fig. 2. NRM-TRM diagram on 1803 (Napier Complex).
(a) NRM-TRM diagram.
(b) Intensity change with temperature of NRM and TRM.
(c) Directional change of NRM and TRM during the experiment.
(d) Zijderveld diagram of NRM.
(e) Zijderveld diagram of TRM.

temperature interval (99 to 305°C) which suggests paleointensity of 70 μT. Figure 3 is an example of mafic dyke. Both specimens of 1902 and 1902X, although taken from the same sample, show quite different behaviors in TRM blocking patterns and in the

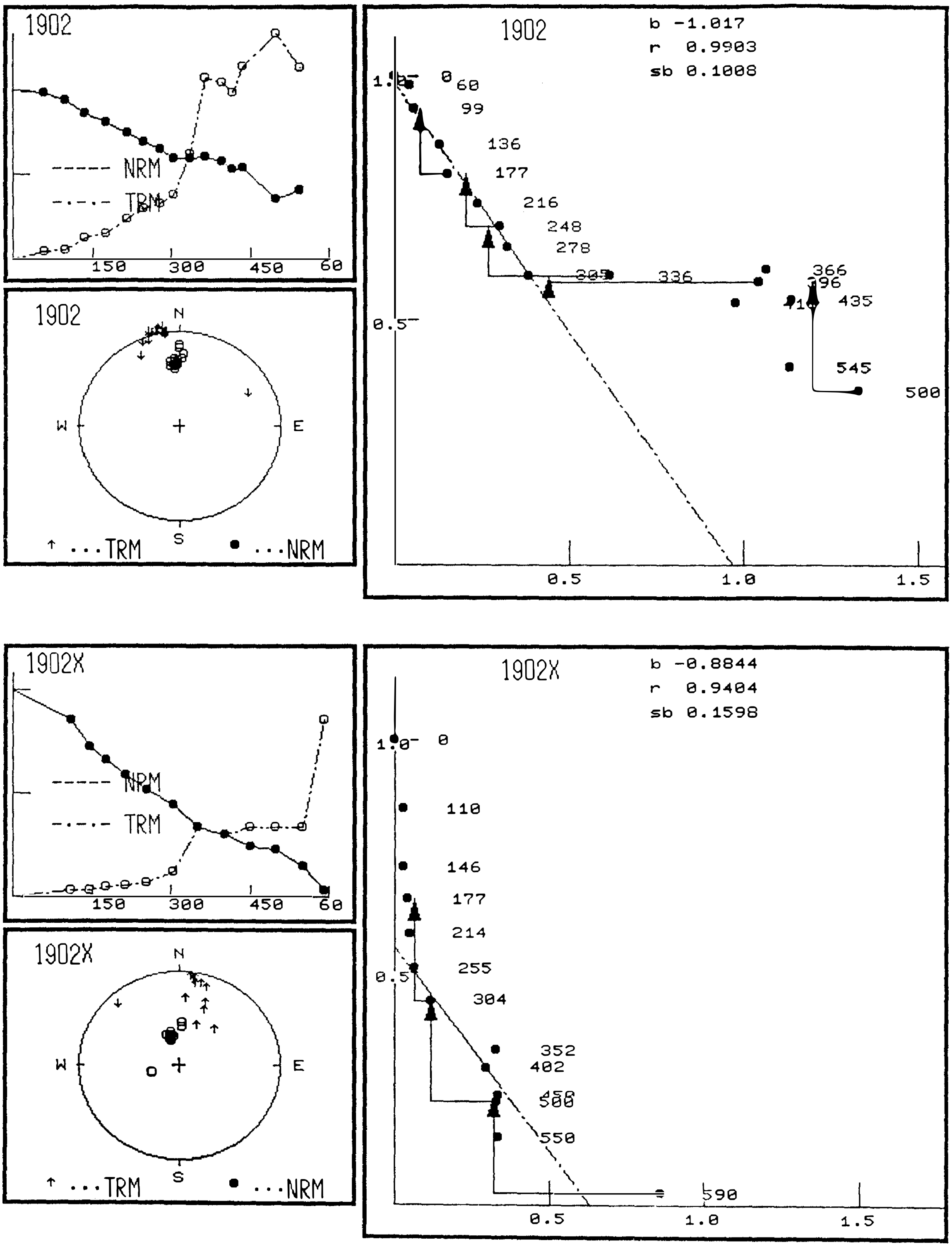

Fig. 3. NRM-TRM diagram on 1902 (Napier Complex).

Table 1. Experimental results.

Site (age)	Sample No.	NRM 10^{-6} Am²/kg	T °C	n	Paleointensity μT
Napier Complex (2.5 Ga–500 Ma)	1803	65	136–305	6	70
	1902	127	216–305	5	50
	1902X	425	255–450	5	44
	1806	126	60–336	9	80
	1907A	33	137–278	5	36
	1907AX	24	304–402	3	86
	1907B	32	99–336	8	86
	2005	42	300–435	6	80
	2005Z	19	450–562	5	22
	2102A	56	99–278	6	85
	2102AU	4.2	159–452	6	25
	2102B	295	177–336	6	85
	2102BU	1008	0–502	8	70
East Ongul Island (480 Ma)	E170	0.73	150–325	5	78
Mawson (475 Ma)	A444-2	0.70	500–600	3	2
	A464-2	0.38	500–600	3	1.2
	A462-2	0.46	400–600	5	0.8
Sør Rondane Mountains (500 Ma)	L738X	1.3	0–550	11	29
	L795X	2.8	0–304	5	46
	L799U	3.0	0–350	6	22
	L801X	5.5	110–255	4	44

T: Temperature of experiment used for calculation.
n: Number of points of experiment used for calculation.

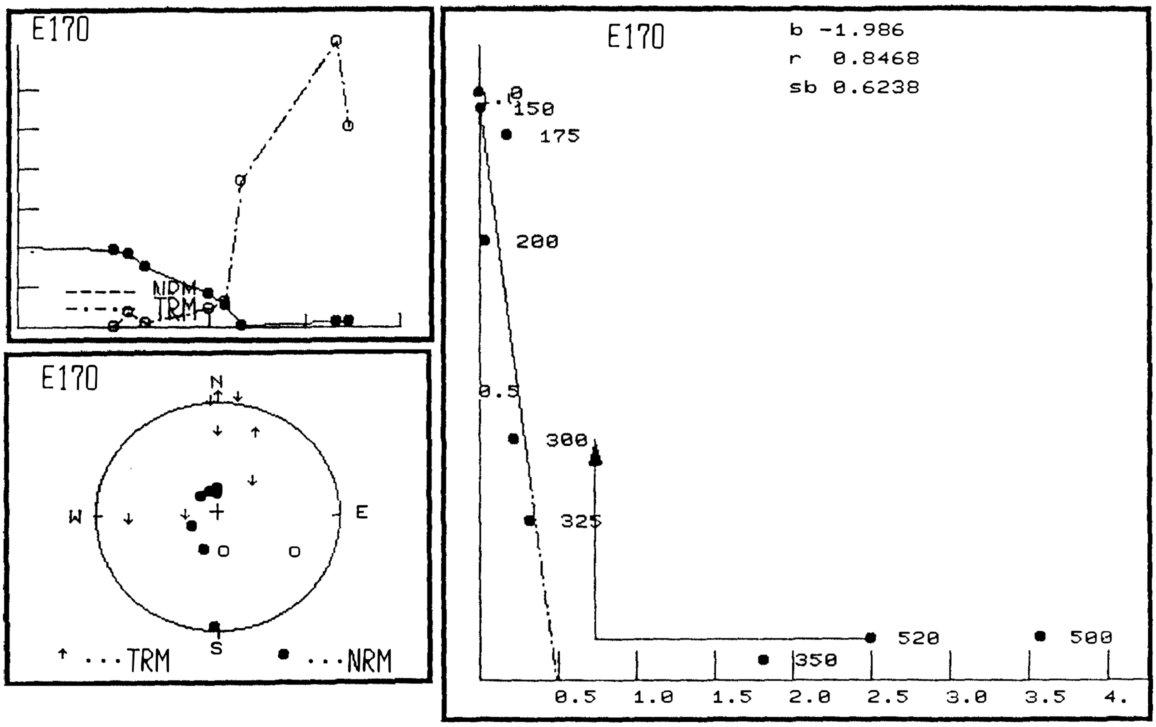

Fig. 4. NRM-TRM diagram on E170 (East Ongul Island).

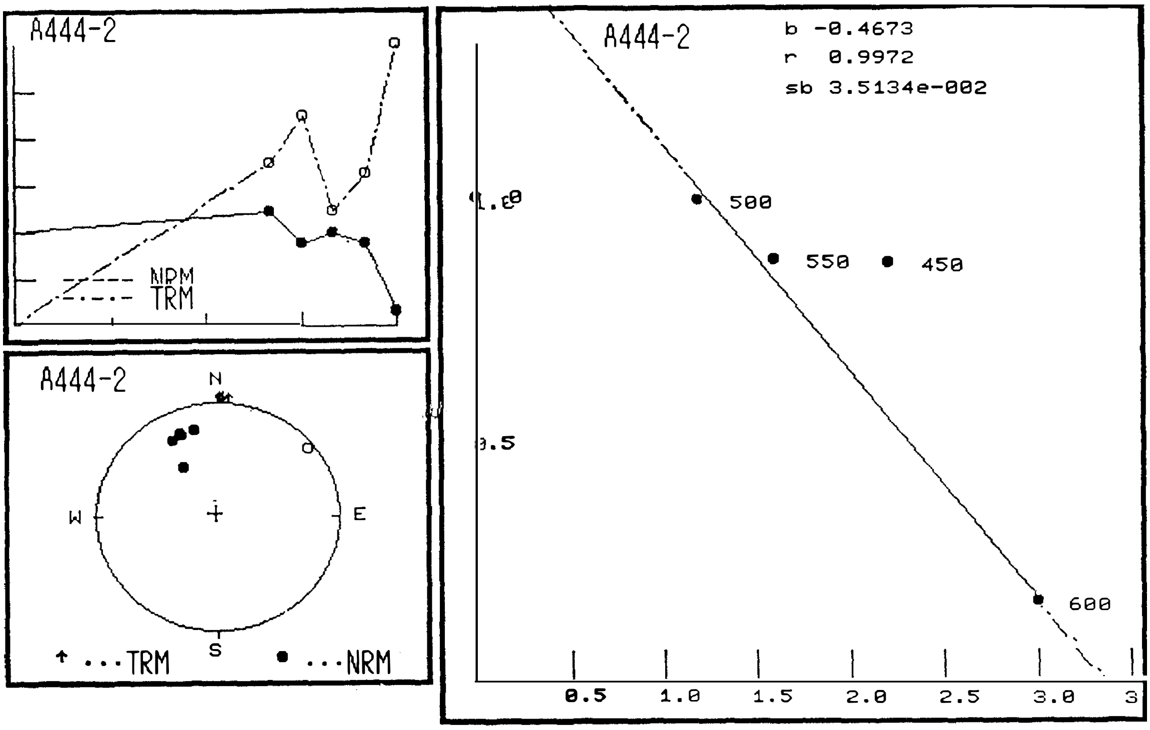

Fig. 5. NRM-TRM diagram on A444-2 (Mawson Station).

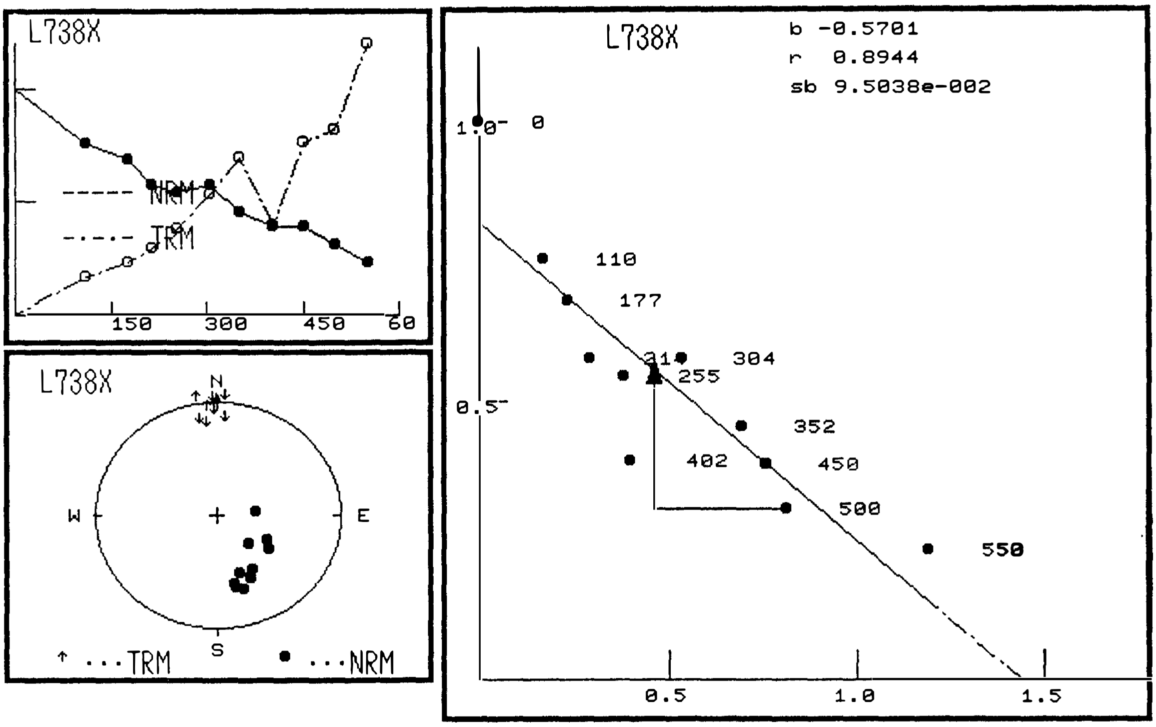

Fig. 6. NRM-TRM diagram on L738X (Sør Rondane Mountains).

NRM-TRM diagram. Duplicate experiments for other dyke samples also show similar irreproducibility. Paleointensities estimated from the linear part of diagrams are shown in Table 1.

Figure 4 is the best example of hornblende gneiss from East Ongul Island, which shows a well defined linear part in a fairly wide temperature interval. From other samples, we could not get a linear part in diagrams.

Typical example of Mawson charnockite is in Fig. 5. Generally we used 40 or 50 μT for laboratory field, but exceptionally 4 μT was used in these experiments on

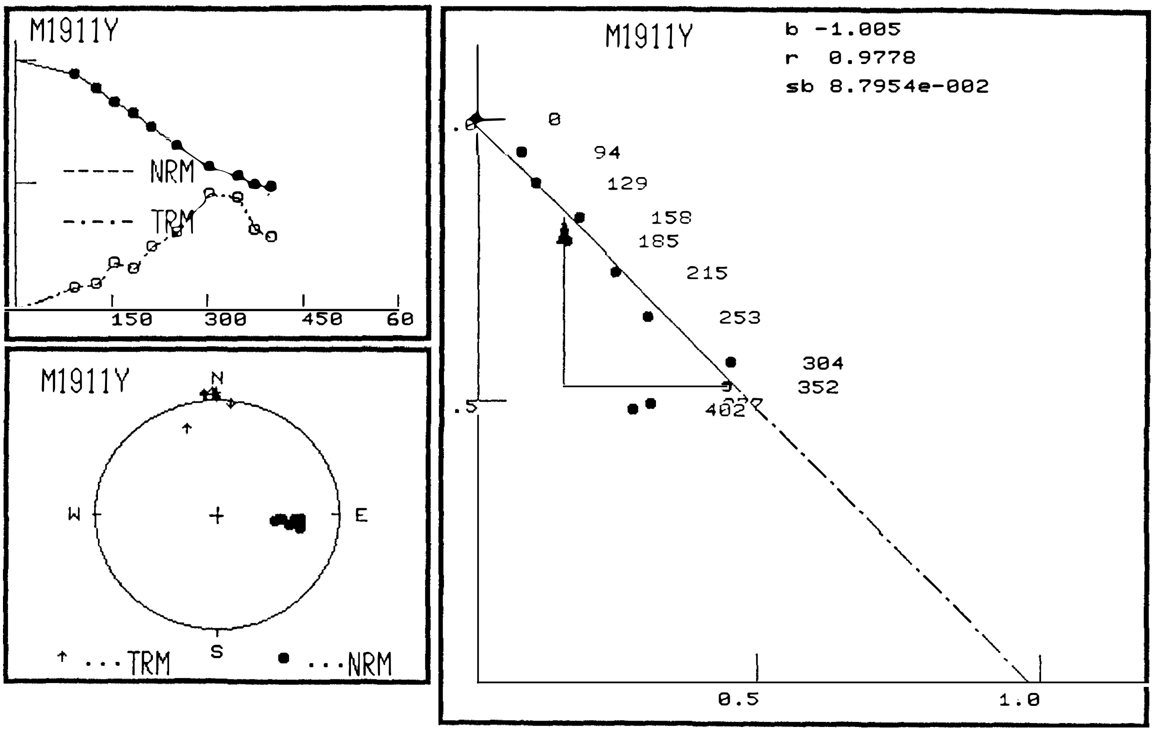

Fig. 7. NRM-TRM diagram on M1911 (McMurdo Sound).

Table 2. Experimental results on McMurdo Sound.

Site (age Ma)	Sample No.	NRM 10^{-5} Am^2/kg	*T* °C	*n*	Paleointensity μT
Black Knob (0.43)	M2216Y	3.2	94–215	5	8.5
Cape Royds (0.68)	M0946Y	390	94–402	10	99
	M0905Y	97	0–503	9	35
Half Moon Crater	M2206Y	253	501–562	4	25
(1.0)	M2206Z	243	502–562	4	26
Castle Rock dyke	M1911Y	784	0–352	9	50
(1.1)	M1911U	737	0–353	6	40
Observation Hills	M2306Y	105	402–542	4	9
(1.18)	M2306Z	118	451–542	4	14
Taylor Valley (2.9)	M0409Z	64	451–592	6	2.8

Mawson charnockite, because they had gotten very large TRM in 50 μT field even at low temperature. It is noted that NRM started to decrease at high temperature. In Fig. 6, the result of syenite (L738) is shown as an example of Sør Rondane rocks. Results on other syenites are listed in Table 1. We could not get linear part from dolerite.

Figure 7 is the best example on McMurdo basalt (M1911), and results of other rocks are in Table 2.

4. Discussion and Conclusion

As shown in Table 1, the samples of the Napier Complex in Enderby Land have widely spread ages and show inconsistent paleointensity values with the same sample. In spite of these difficulties, the obtained paleointensities seem to hold a stable level varying in a limited range of 22 to 85 μT. It is significant to calculate their mean value to recognize an apparent tendency of the past geomagnetic field, because available data are scarce on Archean paleointensities in Antarctica. The mean paleointensity is calculated to be 61 ± 23 μT. This is 20% higher than the observed value in 1975. No radiometric ages are available for the samples treated in this study, but their ages are considered to be 2.5 Ga to 500 Ma according to the previous studies on the Napier Complex by BLACK and JAMES (1983).

We could hardly get significant results on gneisses from East Ongul Island.

As to Mawson charnockites, paleointensities are derived from the data in high temperatures (400 to 500°C), so they are less reliable because some oxidation occurred to alter original magnetic properties of the samples.

The mean paleointensity on Sør Rondane rocks is 35 ± 12 μT. This is 20% lower than the observed value in 1975.

We can find some undesirable factors for the results from McMurdo Sound in Table 2: Marked inconsistency is recognized in the data of two samples (M0946, M0905) from the same site (Cape Royds): The obtained paleointensities from Half Moon Crater and Observation Hills may represent false values because of their dependence on the high temperature data which were possibly spoilt by oxidation.

On the other hand, good reproducibility of the data is revealed in duplicate experiments of the same samples from Half Moon Crater, Castle Rock and Observation Hills; Also these samples have ages very close to 1 Ma. From these data, therefore, we calculated 27 ± 15 μT of the mean paleointensity at 1 Ma. This is 30% lower than the present value.

Our conclusion follows:

(1) Geomagnetic field strength was 20% higher in the period from 2.5 Ga to 500 Ma than today. This was derived from the samples of the Napier Complex in Enderby Land.

(2) Geomagnetic field strength was 20% lower 500 Ma ago than today. This was obtained from the samples of the Sør Rondane Mountains.

(3) Geomagnetic field strength was 30% lower 1 Ma ago than today. This was derived from the samples of McMurdo Sound.

Acknowledgments

The authors wish to thank Dr. H. MAKIMOTO of Geological Survey of Japan and Dr. Y. MOTOYOSHI of National Institute of Polar Research for the samples from the Napier Complex. Part of the experiment was done at Tokyo Institute of Technology, and analysis was done using the program made by the paleomagnetic research group of Tokyo Institute of Technology. We are grateful for the support in various aspects from the group, notably Prof. M. KONO and Dr. H. TANAKA.

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(Received February 27, 1991; Revised manuscript received May 2, 1991)