Paleomagnetic Investigation of Ferrar Dolerite in the McMurdo Sound Region, Antarctica

Minoru FUNAKI*

南極・マクマードサウンドから得られたフェラードレライトの古地磁気

船木　實*

要旨: 南極・マクマードサウンドのライト谷，アランヒルズ，カラペースヌナタ一ク，それにフレミング山に分布する，フェラードレライトの岩床と岩脈から，古地磁気学用試料を採集した．これらの試料に対し，交流消磁および熱消磁を行い，自然残留磁気の安定性を調べ，またヒステレシスおよび熱磁化特性も調べた．その結果，ライト谷，アランヒルズそれにフレミング山の試料は，非常に安定な自然残留磁気を持つが，カラペースヌナタークのそれは，あまり安定でない．カラペースヌナタークの試料中の磁性粒子はおそらく擬単磁区あるいは多磁区構造を持ち，その他の試料のそれは，単磁区あるいは擬単磁区構造を持つと推定される．測定されたすべての試料は正帯磁を示し，計算される古磁極の値は，ライト谷：45.3°S・152.0°W，アランヒルズ：47.0°S・133.2°W，フレミング山：68.6°S・139.5°W，である．これらの古磁極の値は，今まで南極から得られたジュラ紀の古磁極の値と一致する．また今回得られたカラペースヌナタークを除く3個のVGPの値と，今までに得られた7個のVGPから計算されるVGPの中心位置は，南緯53.9°，西経141.8°である．

Abstract: Paleomagnetic samples were collected from a sill and dykes of Ferrar dolerite of the Jurassic age in the Wright Valley, the Allan Hills, the Carapace Nunatak and Mt. Fleming of the McMurdo Sound region. The stability of the natural remanent magnetization (NRM) of these samples was tested against the alternating field (AF) and thermal demagnetization, and the hysteresis and thermomagnetic properties were also measured. The overall results show that the samples from the Wright Valley, the Allan Hills and Mt. Fleming have a reasonably stable NRM; the samples from the Carapace Nunatak were less stable. The NRM carriers are inferred to have a pseudo-single or multi domain structure for the samples from Carapace Nunatak and a single or pseudosingle domain structure for others. All these samples were magnetized to the normal polarity, and the calculated VGP positions were 45.3°S・152.0°W for the Wright Valley, 47.0°S・133.2°W for the Allan Hills and 68.6°S・139.5°W for Mt. Fleming. The virtual geomagnetic pole (VGP) positions obtained in this study are in reasonable agreement with other Jurassic VGPs from Antarctica. The mean VGP center obtained from three values in this study, excluding that of the Carapace Nunatak, and from seven values in the previous studies is located at 53.9°S of latitude and 141.8°W of longitude for Ferrar dolerite.

* 国立極地研究所. National Institute of Polar Research, 9–10, Kaga 1-chome, Itabashi-ku, Tokyo 173.

1. Introduction

In Antarctica, Africa and Tasmania, dolerite sills often intrude into flat-lying sandstone of the Carboniferous to Triassic ages. These dolerite sills are known as Ferrar dolerite in Antarctica. Ferrar dolerite, comprising basaltic lava flows and dykes, is widely found throughout the Transantarctic Mountains. The Ferrar dolerites include all basic igneous rocks of tholeiitic affinities. Characteristically they form sills, dykes, bosses, and laccoliths, as well as extrusive lavas and tuffs, and are younger than the Beacon sandstone but older than the McMurdo volcanics.

Previous paleomagnetic investigations of Ferrar dolerite have been carried out at six sites along the Transantarctic Mountains. The virtual geomagnetic pole (VGP) positions obtained from these rocks were 54°S•136°W for the Theron Mountains (BLUNDELL and STEPHENSON, 1959), 45°S•140°W for the Wright Valley and the Victoria Valley (BULL *et al.*, 1962), 59°S•139°W for the Beadmore Glacier (BRIDEN and OLIVER, 1963), 57°S•168°W and 60°S•137°W for the Dufek intrusion (BECK, 1972; BURMESTER and SHERIFF, 1980) and 41.8°S•134°W for the Dronning Maud Land (LØVLIE, 1979). That is, these VGPs cluster around the present South Pacific.

It is important to ascertain the paleomagnetic pole positions for the period when dolerites were intruding into the Transantarctic Mountains, in order to solve the problem of break-up of the Gondwanaland (MCDOUGALL, 1963). Since the strata surrounding the dolerite are magnetically affected by the igneous activity of the intrusion, it is also important to determine the direction of the natural remanent magnetization (NRM) in the dolerite to evaluate other paleomagnetic data in East Antarctica.

2. Geology and Sampling Sites

Paleomagnetic sampling was carried out in the Wright Valley, the Allan Hills, the Carapace Nunatak and Mt. Fleming of the McMurdo Sound region during two austral summer seasons, 1977–79. The sampling sites are shown in Fig. 1. In the Wright Valley, 22 samples were obtained from the Bull Pass and 4 from the south slope of the Olympus Range behind Vanda Station. These sampling sites are identified as the lower boundary of sill "a" as described by MCKELVEY and WEBB (1962). In the Allan Hills, 19 samples were obtained from 3 different basaltic dykes in the western part of the hills. In the Carapace Nunatak, 4 samples were obtained from one site of basaltic body on the north side of the nunatak. On Mt. Fleming, 15 samples were obtained from a dyke of the east ridge. The orientation of the samples was measured mainly by means of a Sun compass. However, a magnetic compass was used in bad weather.

In the Wright Valley, Ferrar dolerite sills intrude the metamorphic and plutonic basement complex of Precambrian to lower Paleozoic rocks and the flat lying stratum of the Beacon Group sandstone from the Devonian to the Permian age (WEBB, 1963). In the Allan Hills sandstone and diamictite are intruded by the dyke, and are locally overlain by basalt. BALLANCE and WATTERS (1971) estimated the age of the basaltic volcanism at the Allan Hills to be the middle, perhaps the lower, Jurassic period.

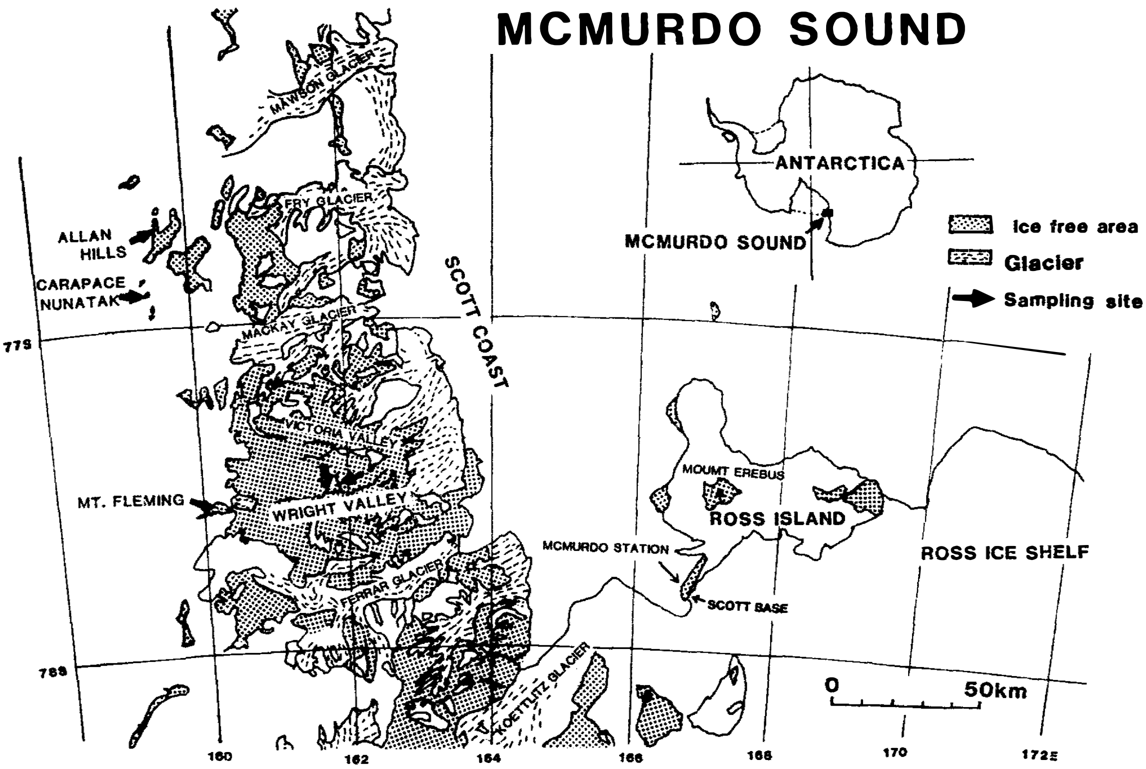

Fig. 1. Sampling sites of Jurassic rock in McMurdo Sound, Antarctica.

According to them, a thick sequence of Jurassic Kirkpatrick basalt, with a thick hyaloclastite breccia with pillow lava, overlies lithic sandstones and conglomerates of the Beacon Group at the Carapace Nunatak. On Mt. Fleming, Ferrar dolerite sills and dykes intrude Triassic siltstone of the Beacon Group (GUNN and WARREN, 1962).

In general, there was no tectonic change for Ferrar dolerite after intrusion in this area, although there was volcanic activity, known as the McMurdo volcanics, in the Cenozoic period.

MCDOUGALL (1963) measured the age of Ferrar dolerites from the Victoria Valley, the Skelton Glacier and the Beardmore Glacier area by the K-Ar method for pyroxenes and plagioclaces; the obtained ages range from 147 to 163 m.y., namely the middle Jurassic age. Geomagnetic polarity is normal interval for these ages according to the international geomagnetic chart by MCELHINNY and BUREK (1971).

3. Magnetic Hysteresis Properties

The magnetic hysteresis properties of pilot samples was measured with a vibrating sample magnetometer at room temperature under a magnetic field of -15.5 to 15.5 kOe. Saturation magnetization (I_s), saturation remanent magnetization (I_R), coercive force (H_c) and remanent coercive force (H_{RC}) were determined from the hysteresis curve, as shown in Table 1. The intensity of natural remanent magnetization, NRM, (I_n) and the ratios (I_n/I_s) and (I_R/I_s) are also listed in the table. For hysteresis analyses, 4 samples were selected from the Wright Valley; A from the south slope of the Olympus Range behind Vanda Station; B, C and D from the Bull Pass; 2 from the Allan

Table 1. Basic magnetic properties of Ferrar dolerite from the McMurdo Sound region.

Sample name	I_s $\times 10^{-3}$ (emu/g)	I_R $\times 10^{-3}$ (emu/g)	H_c (Oe)	H_{RC} (Oe)	I_n (emu/g)	I_n/I_s $\times 10^{-3}$	I_R/I_s
Wright Valley A	10	2.0	101	556	6.206×10^{-5}	6.206	0.200
B	41	4.1	72.5	273	2.160×10^{-5}	0.527	0.100
C	7	2.0	63	417	2.162×10^{-5}	3.089	0.286
D	6	1.4	58	326	1.510×10^{-5}	2.517	0.233
Allan Hills A	502	201.0	205	767	5.636×10^{-4}	1.123	0.400
B	1.6	0.26	18.5	526	2.346×10^{-7}	0.147	0.163
Carapace Nunatak	253	11.0	16	102	3.812×10^{-4}	1.507	0.044
Mt. Fleming	15	1.7	313	1273	1.497×10^{-5}	0.998	0.113

Hills and one each from the Carapace Nunatak and Mt. Fleming, based on differences of color and grain size in the rock.

In the case of the 3 pilot samples from the Wright Valley, the ratio I_R/I_s was of a similar magnitude, but I_n/I_s showed considerable variation. The values of H_c and H_{RC} suggest that the main magnetic grains in these samples have a single or pseudosingle domain structure. In general, fine-grained samples have large H_c and H_{RC} values in comparison with coarse-grained. It may be concluded that the dolerite sill in the Wright Valley is capable of having a stable NRM.

The two pilot samples from the Allan Hills are different from each other in grain size and color. Sample A is fine-grained and dark in color in comparison with sample B. The values of H_c and H_{RC} suggest that the magnetic grains may have a single domain structure in sample A and a single or pseudosingle domain structure in sample B.

The pilot sample from the Carapace Nunatak is the most coarse-grained of all the pilot samples. The values of H_c and H_{RC} suggest that the magnetic grains have an almost pseudosingle or multi domain structure.

The pilot sample from Mt. Fleming shows the finest grain among the pilot samples. As the sample has high values of H_c and H_{RC}, the magnetic grains in this sample probably consist of a single domain structure and the NRM may be the most stable in this study.

4. AF Demagnetization

The pilot samples were demagnetized at 50 or 100 Oe steps up to 800 Oe with an alternating field (AF) demagnetizer. The demagnetizer consists of a two-axis tumbler and a three-layer Mumetal shield case to cancel the effect of the earth's magnetic field. The number of pilot samples chosen was; one from the Carapace Nunatak, 3 from the Wright Valley and Mt. Fleming, and 5 from the Allan Hills. The AF demagnetization curves obtained are shown in Fig. 2. The intensity of NRM of the samples from the Wright Valley was 6.26×10^{-5} to 1.16×10^{-5} emu/g. The intensity of remanence in two of the samples decreased smoothly up to 800 Oe. The median

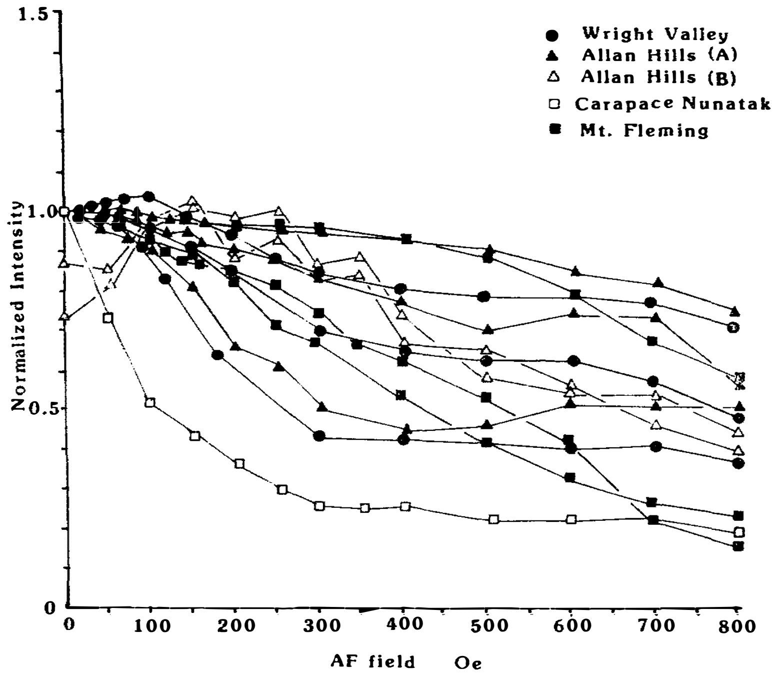

Fig. 2. AF demagnetization curves of NRM of the pilot samples from Ferrar dolerite.

demagnetization field (MDF) of these exceeded 800 Oe. In the case of the remaining sample, the intensity decayed gradually up to 300 Oe, after which there was almost no change up to 800 Oe. The value of MDF was about 250 Oe. The direction of NRM changed within only 3° up to 200 Oe, but showed a large scatter for higher demagnetization steps.

The AF demagnetization curves obtained were 3 and 2, for the samples of Allan Hills A and B respectively. The intensity of NRM before AF demagnetization for sample A was 2.62×10^{-4} to 6.61×10^{-4} emu/g. In general, the NRM of Allan Hills A was demagnetized smoothly up to at least 500 Oe, with MDF values exceeding 300 Oe. The direction of the NRM changed less than 12° in AF demagnetization up to 800 Oe. In the case of Allan Hills B, the intensity of the two pilot samples increased up to 200 Oe and then decreased gradually up to 800 Oe. The direction of NRM for these samples changed within 6° up to 800 Oe. Their basic intensity was very weak (2.35×10^{-7} and 2.04×10^{-7} emu/g), but the NRM was generally stable against AF demagnetization.

AF demagnetization showed that the sample from the Carapace Nunatak is not as stable as the samples from the Wright Valley and the Allan Hills. The intensity of NRM for these samples was 3.50×10^{-4} emu/g. The intensity decreased rapidly up to 300 Oe with MDF of about 100 Oe, and then gradually decreased up to 800 Oe. The direction of NRM changed by about only 6° in the range from 50 to 500 Oe, but it scattered widely at higher fields.

The intensity of NRM for the 3 samples from Mt. Fleming was 4.74×10^{-6} to 1.21×10^{-5} emu/g. The intensity of NRM decreased smoothly up to 800 Oe and the MDF exceeded 400 Oe. As the directional change was within 5° up to 800 Oe, the NRM was very stable against AF demagnetization.

5. Thermal Demagnetization

Pilot samples from the Wright Valley, Allan Hills A and Mt. Fleming were thermal demagnetized in steps up to 600°C. The field intensity in the thermal demagnetizer was less than 20 γ, and the samples were heated in N_2 gas to inhibit oxidation. The representative thermal demagnetization curves obtained are shown in Fig. 3.

The intensity of remanence of the 3 samples from the Wright Valley was different to a factor of two, although the normalized decay curves were very similar to each other: no decrease of intensity up to 500°C, and a steep decrease in the range 500°–600°C. The directional remanence was very stable against thermal demagnetization; directional changes were less than 10° up to 500°C, but at 600°C the directions were random and there was no recognizable trace of fossil remanence.

The thermal demagnetization curves of the 3 samples from Allan Hills A showed a large change of intensity up to 400°C. The intensity in one sample decreased steeply between 350° and 400°C and thereafter the decrease became more gradual. In the other two, the intensity decreased gradually between 350° and 600°C; a small blocking component was found between 350° and 400°C. The direction change in the 3 samples was limited to a few degrees within the range 30°–500°C.

The NRM of the 3 samples from Mt. Fleming decayed smoothly up to 500°C, although a slight initial increase was observed in one sample between room temperature and 100°C; the intensity decreased steeply in the range 500°–600°C. The direction of NRM clustered within 6° against thermal demagnetization up to 500°C. Residual remanences at 600°C were almost zero and the directions scattered widely from the cluster.

Thermal decay curves from these 3 sites (Wright Valley, Allan Hills and Mt.

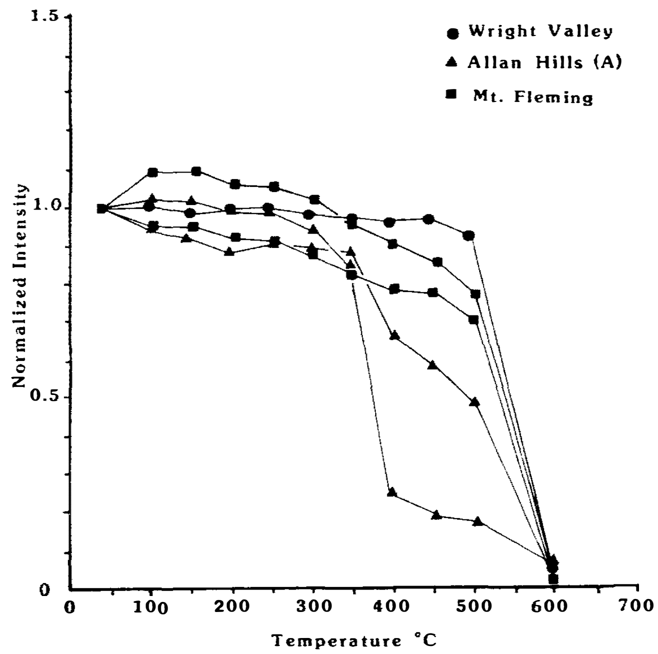

Fig. 3. Representative thermal demagnetization curves of NRM for the samples from Wright Valley, Allan Hills A and Mt. Fleming.

Fleming) clearly show well-defined blocking temperatures. The blocking temperature of the Wright Valley and Mt. Fleming samples exceeds 500°C and there is no recognizable trace of fossil remanence at 600°C. Therefore, it seems that the main magnetic minerals are almost pure magnetite. Since the decay curves of the samples from the Allan Hills show two temperatures, 350°–400°C and 500°–600°C, the coexistence of titanomagnetite and almost pure magnetite may be inferred in these samples.

6. Thermomagnetic Curves and Microscopic Analyses

Thermomagnetic properties were measured by means of a vibrating sample magnetometer from the liquid helium temperature to 700°C under a vacuum of 8×10^{-5} torr.

A typical first run thermomagnetic curve (I_s-T curve) for the Wright Valley is illustrated in Fig. 4a. The I_s-T curves of the 4 pilot samples are essentially the same; the Curie points are 330°C and 543°C in the heating curve and 540°C in the cooling curve. The Curie point at 330°C in the heating curve disappears in the cooling curve, although the I_s-T curve is otherwise reversible. The second run thermomagnetic curve of this sample is exactly the same as the first run cooling curve. Microscopic observations suggest that the main magnetic minerals are magnetite 20–100 μ in diameter and sulphide 10–40 μ in diameter. A minor quantity of hematite grains were also observed around small holes and cracks. As the thermal demagnetization of NRM of the samples from the Wright Valley shows a single blocking temperature higher than 500°C (Fig. 3), the carrier of the NRM can be identified as magnetite with a Curie point at 543°C.

The thermomagnetic curves of Allan Hills A are shown in Fig. 4b. The 1st run (temperature up to 600°C) was reversible, while the 2nd run (to 750°C) was irreversible. A single Curie point at 565°C was observed in both heating and cooling of

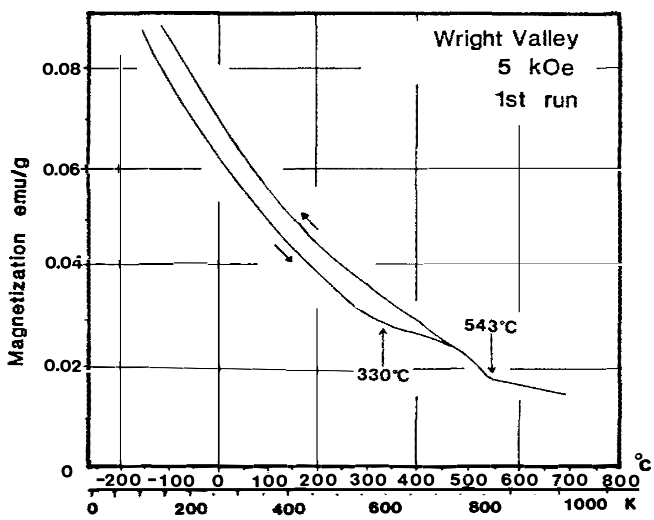

Fig. 4a. A thermomagnetic curve of Ferrar dolerite sill from Wright Valley.

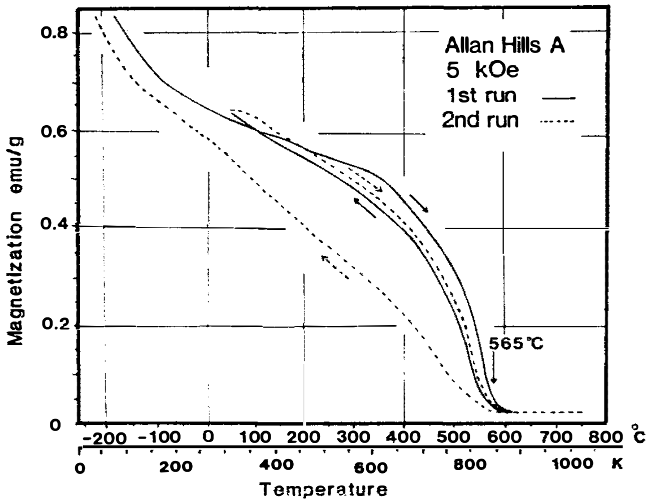

Fig. 4b. A thermomagnetic curve of a dyke (Allan Hills A) from Allan Hills.

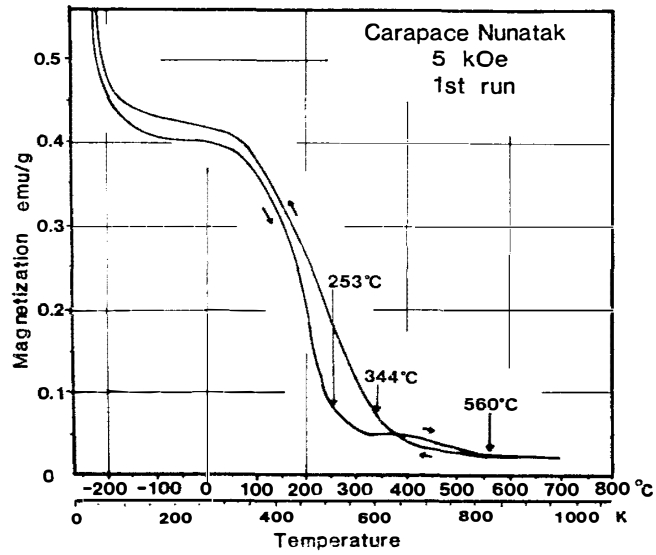

Fig. 4c. A thermomagnetic curve of a basaltic body from Carapace Nunatak.

the 1st and 2nd runs. Since the intensity decreases by about 13% after heating while the Curie point remains unchanged, part of the magnetite grains may have been oxidized to hematite. Consequently, the thermomagnetic curve becomes irreversible when the sample is heated up to 750°C. The magnetic grains in this pilot sample are titanomagnetite, 40–150 μ in diameter. Almost all of these grains are cut by ilmenite lamellas, indicating that they were oxidized at high temperature. Therefore, the sample has a high coercive force of $H_c=250$ Oe in spite of the large grain size and a high Curie point of 565°C. Thermomagnetic curves for Allan Hills B could not be obtained because of the weak saturation moment of $I_s=1.6\times10^{-3}$ emu/g; there were almost no opaque minerals in this sample when examined under a microscope.

The thermomagnetic curve of the Carapace Nunatak, illustrated in Fig. 4c, is irreversible. Curie points were observed at 253°C and 560°C in the heating curve, and 560°C and 344°C in the cooling curve. In the I_s-T curve, a noticeable increase of magnetization may be observed at temperatures below −200°C. This may be due to the paramagnetic component (NAGATA *et al.*, 1972). The main Curie point at 253°C moved to 344°C, and the intensity increased by about 8% compared with the initial value on heating. It is possible that the titanomagnetite grains underwent low temperature oxidation (titanomaghemite). If this is the case, the Curie points of 253°C, 344°C and 560°C may be identified as those of titanomaghemite, titanomagnetite and magnetite respectively. However, titanomaghemites were not observed under the microscope. The diameter of the titanomagnetite grains ranged between 80 and 250 μ.

The thermomagnetic curve of Mt. Fleming is essentially the same as that of the Wright Valley. Curie points were observed at 364°C and 570°C in the heating curve and 575°C in the cooling curve. The intensity increased by about 26% after heating, as compared with the initial value. The result of thermal demagnetization showed that about 80% of the NRM still remained at 500°C and then decreased steeply. Therefore, the carrier of the NRM must be mainly magnetite with a Curie point of 575°C. Actually a small amount of magnetite, at most 8 μ in diameter, was observed under the microscope. The transition point at 364°C may indicate the beginning of the dissolution of pyrrhotite; fine-grained pyrrhotite was observed under the microscope.

7. Discussion

The NRM of 64 samples was measured with a spinner magnetometer or a superconducting rock magnetometer, and these samples were then demagnetized up to 150 Oe to locate stable remanence. The average NRM data from each site together with previous data are listed in Table 2 with calculated VGP position. Table 2 shows the mean intensity of the NRM (R), and the mean inclination (I) and declination (D) of the NRM before (Demag. = 0) and after optimum AF demagnetization (Demag. = 150) for the 4 groups.

Deviation of individual intensity was within 15% of the mean value at each site in the Wright Valley, the Carapace Nunatak and Mt. Fleming. However, it was about 250% for the samples from the Allan Hills; intensities for sites A and B were 43.37×10^{-5} and 0.17×10^{-5} emu/g respectively. The rate of NRM decay by AF demagnetization up to 150 Oe was less than 12% for the samples from the Wright Valley, the Allan Hills and Mt. Fleming, but it was 72% for samples from the Carapace Nunatak. Every sample was magnetized in the normal direction (upward). After AF demagnetization up to 150 Oe, the K value (precision parameter) and the α_{95} (radius of 95% circle confidence) gave reasonably good values for the Wright Valley ($K=136$, $\alpha_{95}=2.4$), the Allan Hills ($K=44.0$, $\alpha_{95}=5.1$), the Carapace Nunatak ($K=74.1$, $\alpha_{95}=10.7$) and Mt. Fleming ($K=1466$, $\alpha_{95}=1.0$).

Since the samples from the Carapace Nunatak have low coercive force as $H_c=16$ Oe, unstable NRM against AF demagnetization and a low main Curie point, it seems that they are unable to have stable NRM; magnetic grains in these samples are of a pseudosingle or multi domain structure. Consequently, the α_{95} value would

Table 2. Paleomagnetic results of Jurassic rock (Ferrar dolerite) in the McMurdo Sound region, Antarctica.

Sampling site		N	Demag.	R $\times 10^{-5}$ (emu/g)	I	D	K	α_{95}	Lat. (S)	Lon. (W)	References
1. Wright Valley		26	0	4.04	−69.0	237.4	19.5	6.5			
			150	3.72	−69.4	237.6	136	2.4	45.3	152.0	
2. Allan Hills	A	14	0	43.37	−66.6	263.9	40.6	6.3			
			150	38.38	−64.2	259.7	42.9	6.1	42.2	133.8	
〃	B	5	0	0.17	−73.2	272.5	73.7	9.0			
			150	0.14	−76.2	277.5	463.0	3.6	62.5	130.1	
	Total	19	0	32.00	−68.4	265.7	44.7	5.1			This study
			150	28.31	−67.6	262.6	44.0	5.1	47.0	133.2	
3. Carapace Nunatak		4	0	26.38	−76.2	207.0	56.8	12.3			
			150	7.48	−67.7	226.7	74.1	10.7	40.9	163.4	
4. Mt. Fleming		15	0	1.30	−81.0	275.1	1100	1.2			
			150	1.43	−80.5	274.4	1466	1.0	68.6	139.5	
5. Theron Mountains		8			−68	64		12	54	136	Blundell and Stephenson, 1959.
6. Ferrar Glacier		57			−76	255	52	2.7	58	142	Turnbull, 1959.
7. Wright Valley		92			−68	250	1877	3	45	140	Bull *et al.*, 1962.
8. Beardmore Glacier		13			−75	244	18	11	59	139	Briden and Oliver, 1963.
9a. Dufek intrusion									60	137	Burmester and Sheriff, 1980.
9b. 〃		91			−69	53	12.4	4.5	56.5	168.0	Beck, 1972.
10. Dronning Maud Land		32			−52.0	50.9	46.6	3.8	41.8	133.5	Løvlie, 1979.

N: Number of samples within each site.
Demag.: Field intensity of optimum AF demagnetization.
R: Intensity of NRM.
I: Inclination of NRM.
D: Declination of NRM.
K: Precision parameter.
α_{95}: Radius of 95% confidence of the pole.
Lat.: Latitude of VGP.
Lon.: Longitude of VGP.

be larger than others. On the other hand, the samples from the Wright Valley, the Allan Hills and Mt. Fleming have high H_c values, NRM blocking temperature and Curie points. Therefore, their NRM are fairly stable and the carrier of NRMs would be of a single or pseudosingle domain structure. From these viewpoints, the VGP data of the Carapace Nunatak can be discarded for this paleomagnetic discussion, and the data of others show significant pole positions of Jurassic time.

The maximum difference in the angles of the mean NRM directions among those 3 sampling sites was 14.1° (between Mt. Fleming and Wright Valley). Even if the previous data are included, the maximum deviation of NRM directions remains the same. In the case of the Wright Valley, the same sampling site was also used in a study by BULL *et al.* (1962). The difference in the angle of mean NRMs is only 4.7° between their value ($I=-68°$, $D=250°$ and $\alpha_{95}=3$) and our value ($I=-69.4$, $D=237.6$ and $\alpha_{95}=2.4$). Since this deviation angle is of the same order of magnitude as the α_{95} value of the respective samples, it may be concluded that the mutual agreement of paleomagnetic direction between the two studies is satisfactory.

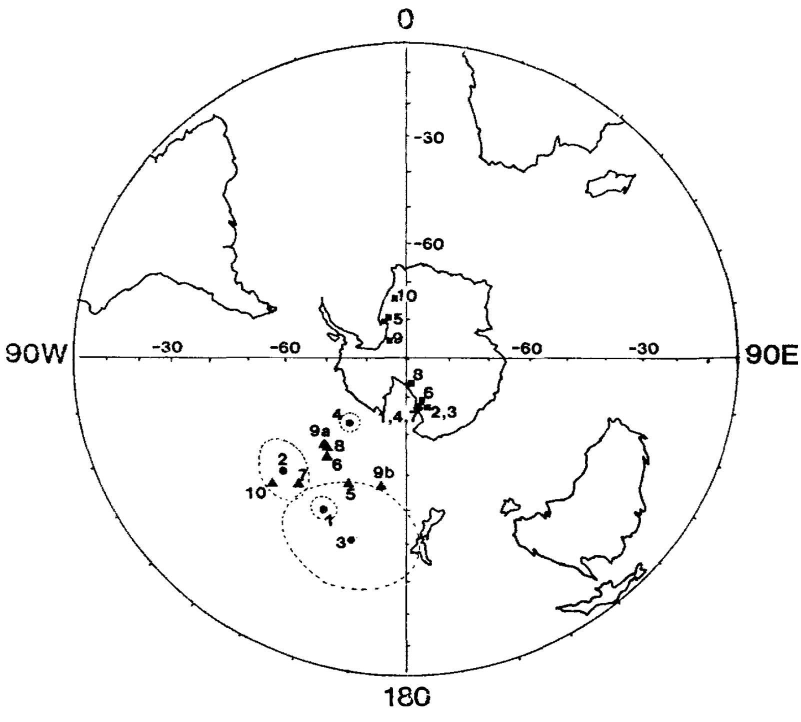

Fig. 5. VGP positions of Jurassic rocks for Antarctica (circles: this study, triangles: previous studies), and the corresponding sampling localities along the Transantarctic Mountains (squares). 1: Ferrar dolerite from Wright Valley (this study), 2: dyke rock from Allan Hills (this study), 3: basaltic body from Carapace Nunatak (this study), 4: dyke rock from Mt. Fleming (this study), 5: Ferrar dolerites from Theron Mountains (BLUNDELL and STEPHENSON, 1959), 6: Ferrar dolerite from Ferrar Glacier (TURNBULL, 1959), 7: Ferrar dolerite from Wright and Victoria Valleys (BULL and IRVING, 1960), 8: Ferrar dolerite from Beardmore Glacier (BRIDEN and OLIVER, 1963), 9a: Dufek intrusion (BECK, 1972), 9b: Dufek intrusion (BURMESTER and SHERIFF, 1980) and 10: Dronning Maud Land (LØVLIE, 1979).

The VGP positions obtained and the circle of 95% confidence from the 4 sites are illustrated in Fig. 5 in addition to the previous Jurassic paleomagnetic poles for East Antarctica. The center of these 10 VGPs, excluding that of the Carapace Nunatak, is located at 53.9°S and 141.8°W and the confidence of radius of 95% circle is 6.3°.

8. Concluding Remarks

The conclusions to be drawn from the present analysis may be summarized as follows: The samples from the Wright Valley, the Allan Hills and Mt. Fleming have a stable NRM representing the magnetic field at the time of the intrusion of Ferrar dolerite. The stability of the NRM was inferred from the results of hysteresis analyses, AF demagnetization and thermal demagnetization. On the other hand, the samples from the Carapace Nunatak may have both a hard and a soft component of NRM. The main magnetic minerals consist of almost pure magnetite in samples from the Wright Valley, Allan Hills (A), and Mt. Fleming, and titanomagnetite in samples from the Carapace Nunatak.

The obtained virtual geomagnetic pole positions in the Jurassic age are 45.3°S•152°W, 47.0°S•133.2°W, and 68.6°S•139.5°W for the Wright Valley, the Allan Hills, and Mt. Fleming respectively. The center of these VGP positions, including the previous Jurassic data in Antarctica, is located on the Southern Pacific Ocean at 53.9°S, 141.8°W at present.

References

BALLANCE, P. J. and WATTERS, W. A. (1971): The Mawson diamictite and the Carapace sandstone formation of the Ferrar group at Allan Hills and Carapace Nunatak, Victoria Land, Antarctica. N. Z. J. Geol. Geophys., **14**(3), 512–527.

BECK, M. E. (1972): Paleomagnetism and magnetic polarity zones in the Jurassic Dufek intrusion, Pensacola Mountains, Antarctica. Geophys. J. R. Astron. Soc., **28**, 49–63.

BLUNDELL, D. J. and STEPHENSON, P. J. (1959): Paleomagnetism of some dolerite intrusions from the Theron Mountains and Whichaway Nunataks, Antarctica. Nature, **184**, 1860.

BRIDEN, J. C. and OLIVER, R. L. (1963): Paleomagnetic results form the Beardmore Glacier region, Antarctica. N. Z. J. Geol. Geophys., **6**, 388–394.

BULL, C. and IRVING, E. (1960): The palaeomagnetism of some hypabyssal intrusive rocks from South Victoria Land, Antarctica. Geophys. J. R. Astron. Soc., **3**, 211–224.

BULL, C., IRVING, E. and WILLIS, I. (1962): Further paleomagnetic results from South Victoria Land, Antarctica. Geophys. J. R. Astron. Soc., **6**, 320–336.

BURMESTER, R. F. and SHERIFF, S. D. (1980): Paleomagnetism of the Dufek Intrusion, Pensacola Mountains, Antarctica. Antarct. J. U. S., **15**(5), 43–44.

GUNN, B. M. and WARREN, G. (1962): Geology of Victoria Land between the Mawson and Mulock Glaciers, Antarctica. N. Z. Geol. Surv. Bull. n.s., **71**, 111.

LØVLIE, R. (1979): Mesozoic palaeomagnetism in Vestfjella, Dronning Maud Land, East Antarctica. Geophys. J. R. Astron. Soc., **59**, 529–537.

MCDOUGALL, I. (1963): Potassium-Argon age measurement on dolerites from Antarctic and South Africa. J. Geophys. Res., **68**(5), 1535–1545.

MCELHINNY, Y. M. W. and BUREK, P. J. (1971): Mesozoic paleomagnetic stratigraphy. Nature, **232**, 98–102.

MCKELVEY, B. C. and WEBB, P. N. (1962): Geological investigation in Southern Victoria Land, Antarctica. N. Z. J. Geol. Geophys., **5**, 143–162.

NAGATA, T., FISHER, R. M. and SCHWERE, F. C. (1972): Lunar rock magnetism. Moon, **4**, 169–186.

TURNBULL, G. (1959): Some palaeomagnetic measurements in Antarctica. Arctic, **12**(3), 151–157.
WEBB, P. N. (1963): Geological investigation in Southern Victoria Land, Antarctica. N. Z. J. Geol. Geophys., **6**, 361–387.

(Received July 5, 1982; Revised manuscript received August 25, 1982)