Palaeomagnetic Studies on Pre-Cambrian Gneiss of Ongul Islands, Antarctica.

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オングル島近傍の前カンブリア紀片麻岩による古地磁気学的研究

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要　旨

第1次および第3次南極観測隊派遣の際，古地磁気学研究の目的をもって，東オングル島昭和基地附近の先カンブリア紀の片麻岩（biotite hornblende granodioritic gneiss）を方向をつけて採集してきた．これらの岩石の自然残留磁気(NRMと略す）の測定結果から，岩石生成時の地球双極子の方向を計算すると，Lat.＝19°N, Long.＝167°W となる．また，岩石の片理面が岩石生成時には水平面であったと仮定し補正しても，Lat.＝3°N, Long.＝107°W となる．いずれにしても岩石の NRM の方向から推定される地球双極子軸の方向は，西太平洋赤道地域にあったこととなり，先カンブリア紀以来，地球磁極（すなわち地軸も）および南極大陸相互は，広範な移動および回転をしてきたことが示された．この論文では，以上の結論を確認するため，岩石の NRM が岩石生成時から，そのまま保存されてきたかどうかというテストを実験室で行なった結果についても同時に示されている．

1. Introduction

Palaeomagnetic studies of tracing back the secular variation of the geomagnetic field throughout geologic times by means of a large number of rocks of various regions over the earth have recently been developed so systematically in detail that discrepancies among results derived from different regions have become significant, suggesting, for example, mutual movement between different continents. It seems that palaeomagnetic studies of the Antarctic rocks are particulary important because now the Antarctic is the only continent where no palaeomagnetic research has been done. Results of palaeomagnetic research of the Antarctic rocks would possibly give some informations about crustal movement of this continent as well as add a new series of significant data to those already obtained on the other continents.

From this view point, a number of rock-samples from East Ongul Island, where Syowa station for Japanese Antarctic Research was set up, were collected at the opportunities of our expeditions in February 1957 and in January 1959. The locality

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of Syowa station is approximately 69°00′S in latitude and 39°35′ E in longitude.

As has already been reported[1,2], Ongul Islands and their vicinity are composed mostly of Pre-Cambrian gneiss and granodiorite.

At three sites in East Ongul Island, shown in Fig. 1, rock-samples were taken in January 1959, while in February 1957 samples were taken at the same place as one of these three sites, that is, site A in the figure. All of these rocks are *biotite hornblende granodioritic gneiss*. These metamorphic rocks *in situ* have clear banded structure, dip and strike of the gneissosity planes being ranged from 51° to 54° and from N 20°W to N 01°W respectively.

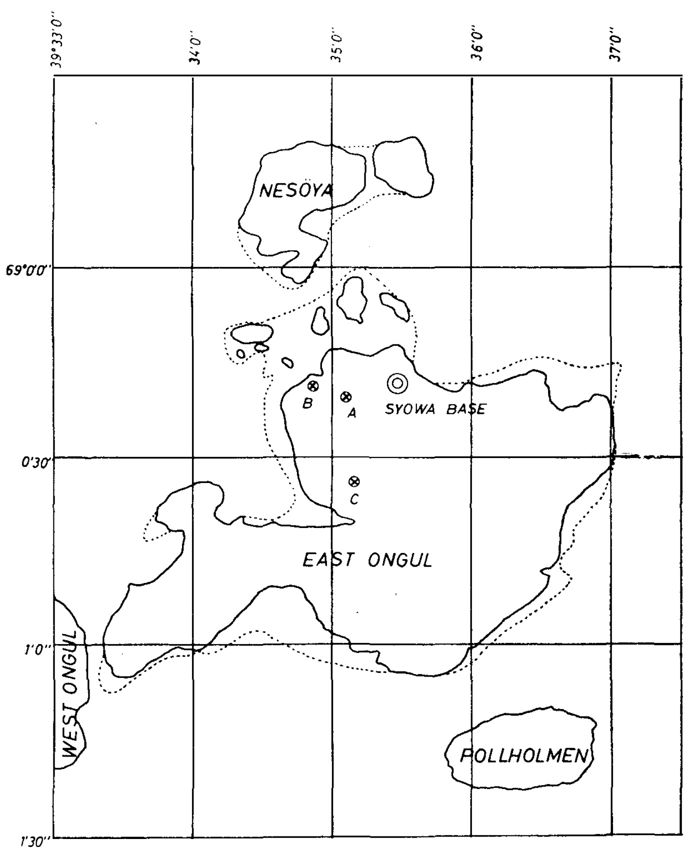

Fig. 1. Sampling sites in Ongul Islands, the Antarctic.

2. Laboratory test of stability of remanent magnetization of specimens

In course of palaeomagnetic studies of rocks, stability and reliability of their natural remanent magnetization (NRM) must be examined, and those specimens having unstable remanent magnetization must be eliminated according to the best possible methods of criterion. In present case, three different ways of examination are adopted. They are (a) alternating magnetic field demagnetization, (b) determination of ferromagnetic minerals in the rocks, and (c) thermal demagnetization[3].

As shown in Fig. 2, for example, stable remanent magnetization is kept almost constant against alternating magnetic field (AC) demagnetization up to 400 *Oe* in field intensity, indicating that the concerned NRM has been and is extremely stable. In this case, residual magnetization after AC-demagnetization up to various field intensities always kept nearly the same direction, as illustrated by full-circles in Fig. 3.

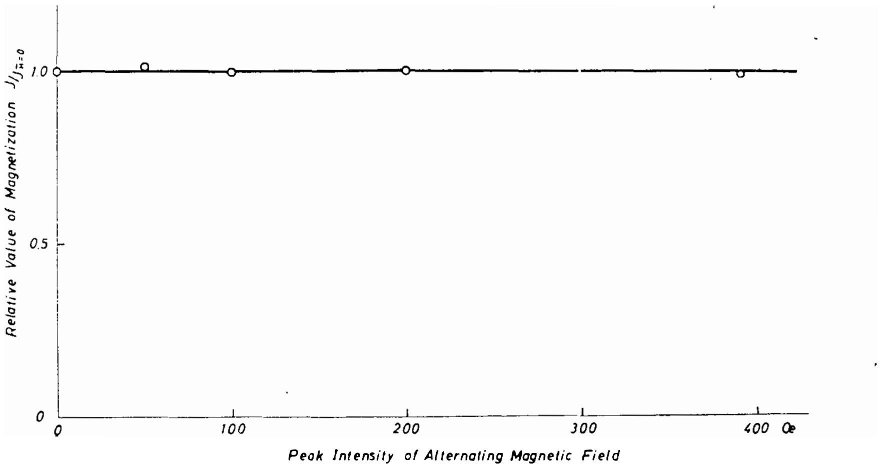

Fig. 2. Change in the intensity of stable remanent magnetization with the demagnetization by alternating magnetic field.
Sample: B-2

On the other hand, NRM of some specimens is rather unreliable, as illustrated by hollow circles in Fig. 3, where direction of residual magnetization after the AC-demagnetization changes gradually according as the intensity of AC field becomes larger. Changes in intensity of NRM after AC demagnetization in this case is of increase with increase in AC-field intensity, as shown in Fig. 4. According to the results of studies by the authors and their colleagues, this kind of instability of NRM against AC-demagnetization is interpreted as superposition of two kinds of NRM and as showing that secondary magnetization of weak intensity and of low stability (mostly due to isothermal remanent magnetization produced under the effect of primary NRM) is reduced by AC-demagnetization, the remaining NRM representing primary NRM of high stability. It has been proposed therefore that this kind of NRM after demagnetizing the unstable part could be used for palaeomagnetic purposes. For the sake of safety, however, rock specimens with this kind of unstable magnetization were eliminated in the present study.

Ferromagnetic minerals separated from the rock specimens are composed mostly of almost pure magnetite, whose Curie-point is 580°C, and of a little amount of almost pure haematite, Curie-point of which is 680°C. It is shown, however, by an example of the thermal demagnetization curve of the rock sample having stable NRM in Fig. 5 that haematite alone is responsible for NRM of these rocks. It is ascertained further that thermo-remanent magnetization (TRM) of the same specimens produced in laboratory in the present geomagnetic field is larger than that of NRM by about 50% and this discrepancy is mainly due to TRM of magnetite.

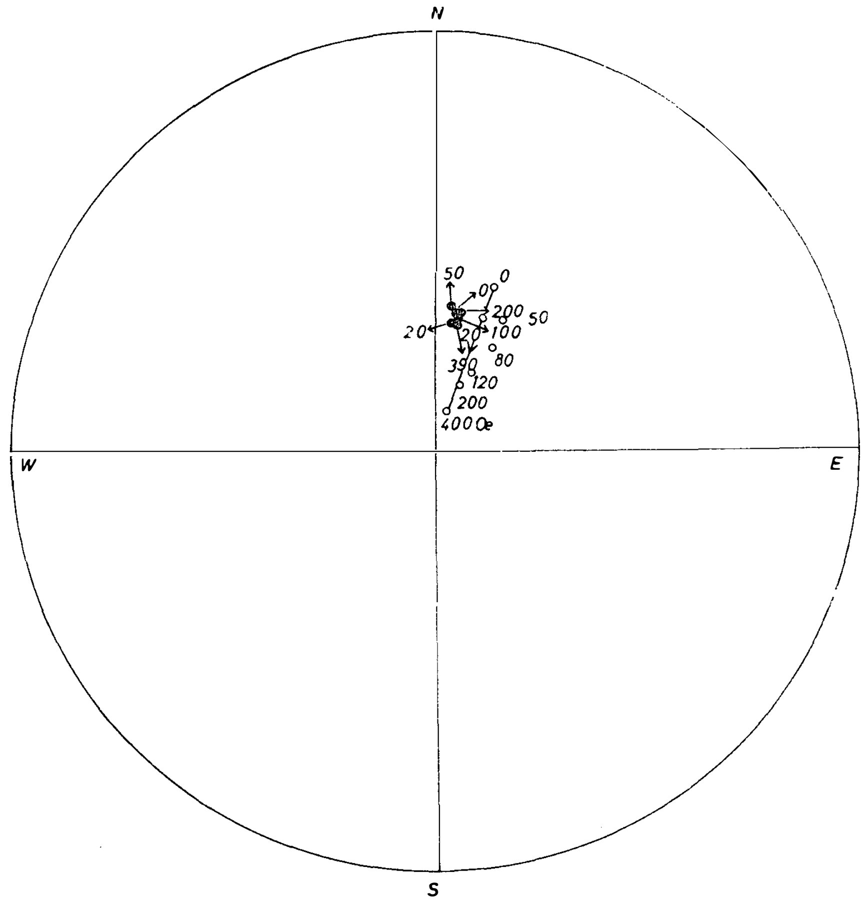

Fig. 3. Change in the direction of remanent magnetization with the demagnetization by alternating magnetic field.
● Sample: B-2
○ Sample: C-8

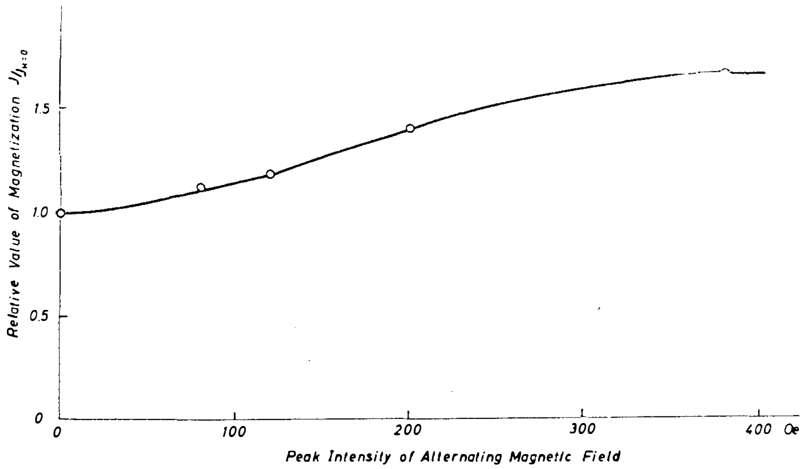

Fig. 4. Change in the intensity of remanent magnetization with the demagnetization by alternating magnetic field.
Sample: C-8

Summarizing the above-mentioned results of laboratory tests, it may be concluded that NRM of rock specimens concerned here is composed mostly of remanent magnetization of haematites and it is very stable.

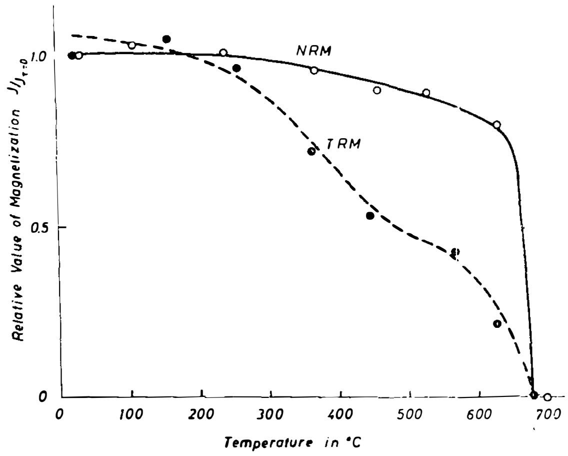

Fig. 5. Change in the intensity of remanent magnetization with thermal demagnetization.
Sample : B-4
○····N. R. M.
●····T. R. M.

3. Direction and intensity of natural remanent magnetization

The number of rock specimens having stable NRM according to the criterion discussed in the foregoing section is 4 from A-site, 8 from B-site and 6 from C-site.

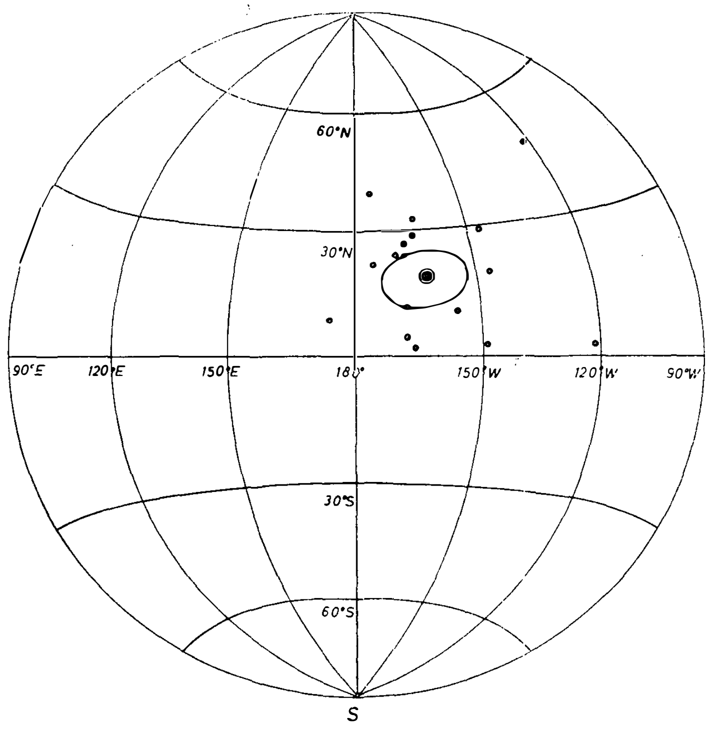

Fig. 6. Positions of the dipole's south pole corresponding to each sample.

Intensity and direction of NRM of these 18 specimens are given in Table I. As for intensity of NRM, it may be said that it is rather homogeneous for all 18 samples.

Table I.

Sample No.	Intensity (emu/gr × 10^5)	Direction		Corrected direction	
		Decli.	Incli.	Decli.	Incli.
A 1	6.2	N 33° E	78°	N 73° E	31°
A 2	5.8	N 20 E	40	N 41 E	8
A 3	7.6	N 16 W	50	N 31 E	30
A 4	9.4	N 8 W	60	N 44 E	30
Pole position derived from mean values of the above four. lat.=18°N, long.=137.5°W. Corrected. lat.=2.5°S, long.=96°W.					
B 1	12.2	N 34°W	69°	N 52° E	32°
B 2	18.6	N 10 W	68	N 52 E	33
B 3	9.0	N 37 W	61	N 36 E	40
B 4	14.4	N 49 W	40	N 2 E	44
B 5	20.4	N 9 W	41	N 25 E	22
B 6	22.2	N 42 W	58	N 38 E	46
B 7	13.0	N 29 W	58	N 33 E	40
B 8	21.2	N 33 W	66	N 46 E	42
Pole position derived from mean values of the above eight. lat.=20.5°N, long.=166.5°W. Corrected. lat.=3.5°N, long.=107.5°W.					
C 1	5.8	N 27°W	39°	N 10° E	27°
C 2	6.8	N 29 W	42	N 14 E	30
C 3	9.2	N 35 W	64	N 39 E	42
C 4	8.6	N 50 W	70	N 47 E	48
C 5	33.6	N 35 W	62	N 45 E	43
C 6	39.2	N 31 W	50	N 29 E	40
Pole position derived from mean values of the above six. lat.=16°N, long.=168°W. Corrected. lat.=2.5°N, long.=115.5°W.					

Assuming as usual that these directions have kept those of the magnetic field at this locality caused by the earth's centred dipole at the epoch of formation of these rocks, average positions of the south pole of the assumed centred dipole for the three groups, A, B, and C are given also in the Table I. The three sets of the values are in rather good agreement with each others.

The average position of the dipole's south pole derived from all of 18 samples is given as

$$\text{Lat.}=19°\text{N}, \quad \text{Long.}=163°\text{W},$$

radius of circle of confidence of 5% being 7°. Positions of the dipole's south poles corresponding to each sample are plotted in Fig. 6 together with the total average pole position. If we assume that there has been no appreciable crustal deformation since the time of production of NRM of these rocks, the above-mentioned result indicates that the position of the south pole of the geomagnetic centred dipole, and therefore an approximate position of the earth's rotation pole, was situated at 19°N in latitude and 163° W in longitude at the time of formation of those rocks in Pre-Cambrian.

It must be noted, however, that inclination of the gneissosity planes in the concerned locality is remarkable and is fairly homogeneous over a wide area, not only in the Ongul Islands but also in the area of exposed rocks on the coast of Lützow-Holm Bay. At present, the process of formation of the concerned geological structure has not yet been made clear. According to the preliminary results of geological and geomorphological studies of this region[1)4)], however, it seems that the inclination of the planes of gneiss of banding was caused by a certain crustal deformation after completion of metamorphism of those rocks concerned. If we assume, then, that the gneissosity-planes were horizontal when thermal metamorphism of this area took place and consequently thermo-remanent magnetization of those rocks was produced, the direction of magnetic polarization of each specimen can be transformed to that referred to the assumed ancient coordinates of the horizontal plane and the meridian. The direction thus transformed of each specimen is shown in Table I, where the average pole positions for the three groups are also given. Then the total average position of the south pole of the geomagnetic dipole becomes

Lat. = 3°N, Long. = 107°W,

where radius of circle of confidence 5% is 7°. It may be concluded from this result that the south pole of the earth's magnetic dipole was situated approximately at about 100°W in longitude near the equator in Pre-Cambrian or in a little later geologic period, so far as there has been no remarkable drift and rotation of the Antarctic continent. The assumption for correcting the direction of magnetic polarization of rocks by referring to their gneissosity-planes, adopted in the present study, may be still more or less ambiguous. Roughly speaking, however, it might be said, from both uncorrected and corrected data, that the pole was situated around the equator in the Western Pacific Area in that geologic time.

4. Comparison with data from other continents

In the southern hemisphere, palaeomagnetic studies on Pre-Cambrian rocks have already been carried out in Australia[5)] and in South Africa[6)]. For comparison, the results of these Australian and South African data are summarized in Table II, together with the present one. Comparing these results to each other, it will be seen that the pole position derived from the present data of the Antarctic is in rather good agreement with that derived from the South African data, while the Australian data, especially two of the three results in the Table, are appreciably different from the upper two.

It might be suggested that the rough agreement between the present and the South African can be attributed to the condition that these two localities are situated at nearly same longitude, distance between them being about 35° along the meridian circle.

Table II.

Locality	Author	Pole position	
		Lat.	Long.
Antarctic	Nagata & Shimizu	3°N	107°W
South Africa	Gough	8°S	137°W
Australia	Irving & Green	30°N	121°W
		51°N	18°W
		6°N	14°W

As for the Pre-Cambrian pole position, a number of data have been reported with respect to European and American rocks in the northern hemisphere[7]. These northern hemisphere data do not give any unique pole position, even in sense of rough approximation, of the earth's dipole. It may be said, however, that most of those pole-positions derived from rocks from both northern and southern hemispheres are situated between the equator and the 35°N latitude circle. Then, summarizing all data obtained hitherto, including the present Antarctic one, it may be most probable to suppose that the pole-position of the earth's magnetic dipole was situated near the equator in Pre-Cambrian.

This is a report of the first step of palaeomagnetic studies on Antarctic rocks, and it can be expected that further extension of palaeomagnetic studies on other Antarctic rocks, such, for example, as red stones, will give us more detailed information about not only the pole-position in old geologic times but also some behaviour of movement of the Antarctic continent, if any.

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