14. *On the Natural Remanent Magnetization of the Lava composing the Central Cone of Volcano Mihara.*

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1. In his previous paper[1], the writer described certain magnetic properties, such as the magnetic susceptibility and the residual magnetization, of several samples of the ejecta of Volcano Mihara, comparing them with their petrography and chemistry. The values of the magnetic susceptibility of the central cone ejecta were too small compared with those expected from the results of magnetic survey around the crater of the volcano, which is probably due to the presence of natural remanent magnetization in the rocks of the central cone. As is well known, a knowledge of the direction and intensity of the natural remanent magnetization of rocks is of importance not only in problems concerning the interpretation of the results of magnetic surveys, but also in a study of the magnetic properties of rocks, seeing that it is closely related to the history of the rocks.

As a preliminary study of the problem, the direction and intensity of the natural remanent magnetization of several samples of ejecta from the central cone of Volcano Mihara were observed by means of the magnetometric method.

The instrument was an astatic magnetometer, in which the vertical distance between two magnets and the horizontal distance between one magnet (under) and the centre of the test sample were 70 *cm* and 21·3 *cm* respectively. The sensitivity of the astatic magnetometer S/M could be varied from 2×10^3 to 60, where S and M denote respectively the scale reading of the deflection of the magnet system and a component of the total magnetic moment of the test sample. The observational error was $\pm0{\cdot}5\,\%$, even when the magnetic force affecting the compensating magnet was neglected. For every sample measured, the sensitivity of the instrument was calibrated twice by means of a Helmholtz coil.

The test sample was held on a brass universal stage, on which the sample could be rotated around both its horizontal and vertical axes.

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1) T. NAGATA, *Bull. Earthq. Res. Inst.*, 17 (1940), 102.

The magnetic intensity of the component in any direction through the centre of the sample could be measured by rotating the sample around the vertical axis through angles of from 0 to 2π, and around the horizontal axis from 0 to π. As examples, two measurements are shown in Figs. 2, 3, where N and S point to the North and South poles of magnetization of these rocks. Analysing these results by means of Gauss's method, it was possible to determine the direction of the natural remanent magnetization, with a mean error of less than 2 degrees in angle. This method of analysis had already been used in the experiments of S. Nakamura[2)] and M. Matuyama[3)] for determining the direction of the permanent magnetism of igneous rocks.

2. The measured samples were five specimens of the An'ei lava flow in the caldera, which was ejected in 1778; three specimens of the Meizi-Taisyô lava

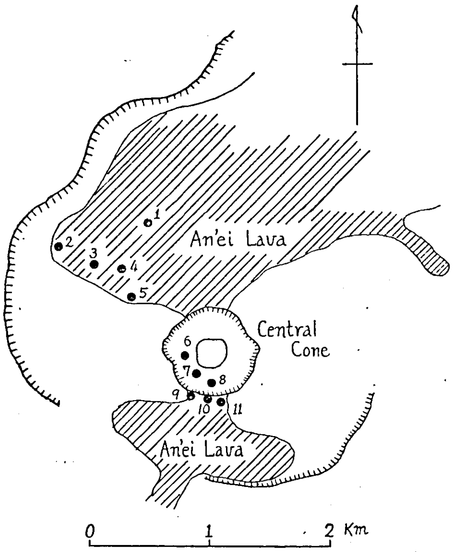

Fig. 1. Localities of measured samples.

Table I.

No.	Locality	Natural Remanent Magnetization			Specific Susceptibility	Q_n
		dip	$\Delta\delta$	Specific Intensity		
1	An'ei Lava Flow (in caldera)	45°	+5°	0·020		
2	〃	42	+8	0·023	$0·52\times10^{-3}$	88
3	〃	50	+9	0·025	$0·48\times10^{-3}$	116
4	〃	48	−2	0·032		
5	〃	51	−5	0·029	$0·56\times10^{-3}$	115
6	Meizi-Taisyo Lava (Southern part of bottom)	47	+2	0·016		
7	〃	52	−3	0·019	$0·31\times10^{-3}$	135
8	〃	48	0	0·016	$0·34\times10^{-3}$	106
9	An'ei Lava (Southern part of central cone)	46	+3	0·036	$2·21\times10^{-3}$	34
10	〃	50	+8	0·021		
11	〃	49	+14	0·017	$0·76\times10^{-3}$	50

2) S. NAKAMURA and S. KIKUCHI, *Proc. Phys. Math. Soc. Japan* 6 (1912), 268.
3) M. MATUYAMA, *Proc. Imp. Acad. Tokyo*, 5 (1929), 203.

ejected during 1911-1914, and three specimens of An'ei lava from the southern part of the central cone. The localities of these samples are plotted in Fig. 1 and described in the second column of Table I.

Generally speaking, all these rocks are basalt, a large number of which are "Miharaite," named by S. Tsuboi.[4] All these samples were cut off from a large lava sheet that appeared to be in the same position and direction that they were when they solidified from the viscous state at high temperature. Some difficulty was experienced in determining the direction of the magnetic meridian at the very point from which the sample was taken, for the reason that the magnetic declination directly on the surface of the lava block usually deviated a few degrees from the normal value, as a result of the presence of magnetized rock. In order to ascertain the magnitude of this deviation, the distribution of declination near the lava block was roughly observed on the spot. Several outstanding examples of these observations are shown in Fig. 4, where the value of ordinate r represents the normal distance from the surface of the lava block. As will be clear from these examples, the declination at a point a few centimetres from the surface of the lava block deviated as much as 20 degrees from the normal direction. This anomalous deviation, however, vanishes rapidly with increasing distance

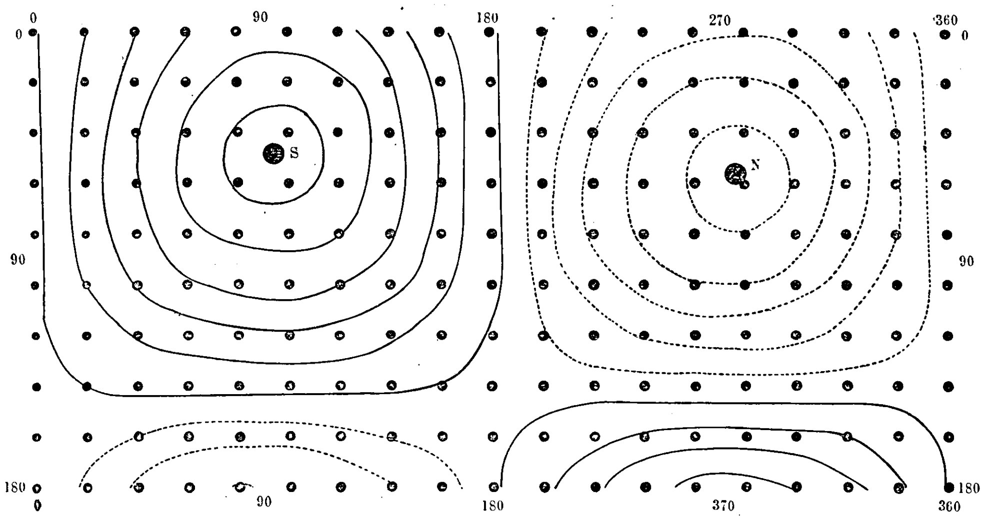

Fig. 2. Sample No. 10.

from the surface of the lava sheet (roughly speaking, in proportion with $1/r^2$ or $1/r^3$.), the local deviation in declination becoming less than one degree at a point 40 cm distant from the surface. In our case, therefore, we adopted the magnetic meridian of a point 50 cm distant

4) S. Tsuboi, *Journ. Coll. Sci. Tokyo Imp. Univ.*, 43, [6] (1920).

from the surface of the lava as the present magnetic meridian at the place where the rock sample was taken.

The observed results of the intensity and direction of natural remanent magnetization of these rocks are shown in Table I, where W,

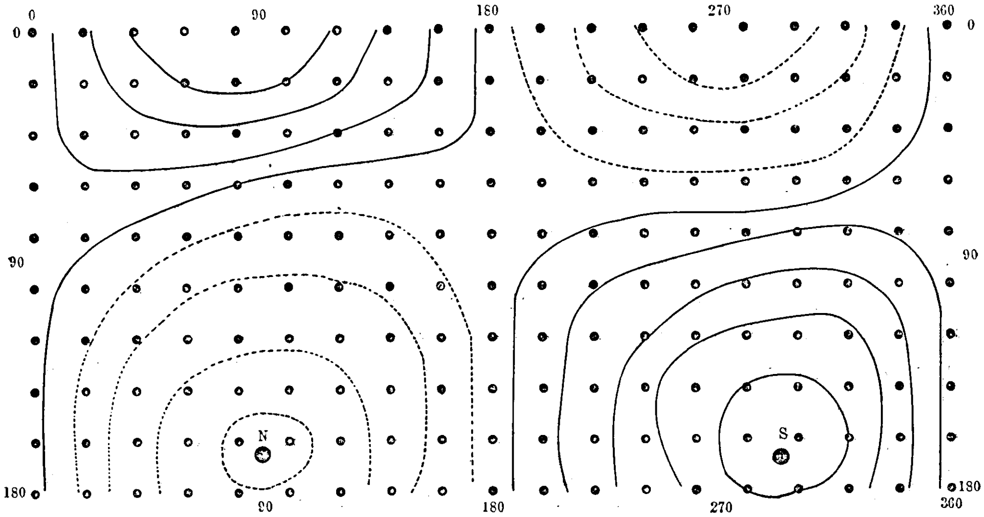

Fig. 3. Sample No. 2.

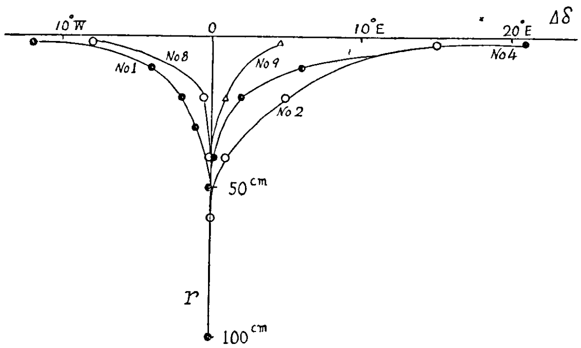

Fig. 4. Deviations of geomagnetic declination near the surface of the Mihara lava.

E in the column under $\Delta\delta$ denote respectively the westerly and easterly deviations from the present earth's magnetic meridian. The directions of the natural remanent magnetization are also plotted in Fig. 5, while the vectors of the directions projected on the horizontal and the N-S vertical p'anes are given in Fig. 6. Table I also gives the specific susceptibilities at 0·45 Gauss, as measured by the ballistic method mentioned in the previous paper.

3. The declination of the natural magnetization of the rocks de-

viated several degrees East or West from the present magnetic meridian, at the place where the rock was taken.

Part of the fluctuations is due to the magnetic anomalies in the vicinity of the place where the rock sample was taken. As shown in the writer's previous paper[5], the magnetic anomaly amounts to several degrees in declination there. As one cause of the fluctuation, there is the fact that the magnetization of the rocks was not uniform, especially in that part near the surface of the lava block. A fluctuation of several degrees is also seen in the dip of the magnetization, the cause for which may be the same as that for the declination.

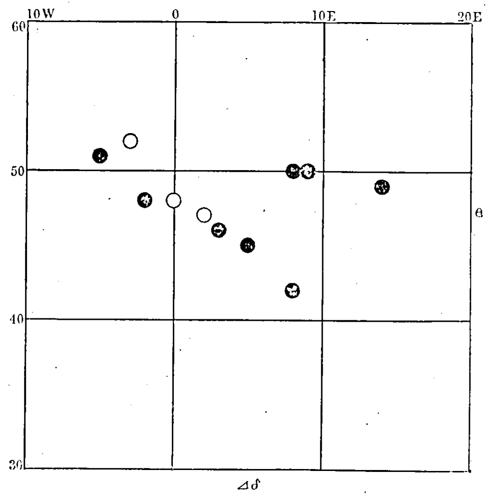

Fig. 5. The directions of natural remanent magnetization.

In every sample, the direction of the natural remanent magnetiza-

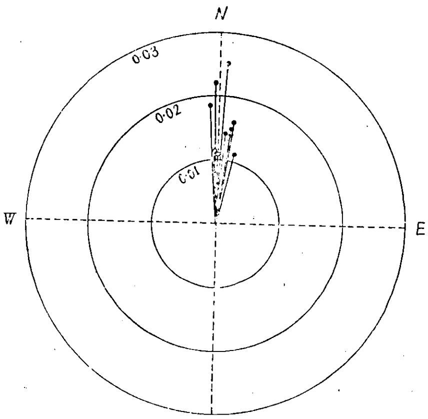

Fig. 6 (a) Direction and intensity of natural remanent magnetization projected on horizontal plane.

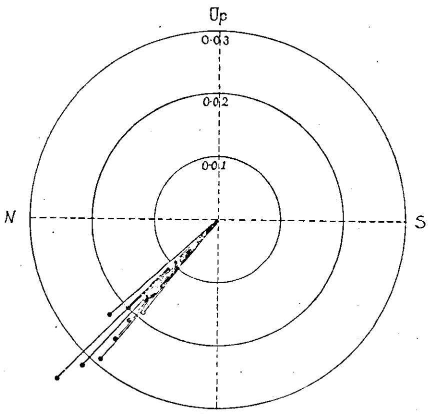

Fig. 6 (b) Direction and intensity of natural remanent magnetization projected on *N-S* vertical plane.

tion is, however, nearly the same as that of the present geomagnetic force in Oosima. The dip of the magnetization of the rock is 41°～52°, while the mean dip of the earth's magnetism in the vicinity of the

5) T. NAGATA, *Bull. Earthq. Res. Inst.*, 16 (1938), 288.

central cone of Volcano Mihara is 47°∼51°;[6] the difference between the declination of magnetization of the rocks and the magnetic meridian being −5°∼+14°. The remanent magnetization, therefore, is the thermo-remanent magnetization, the result of cooling of the lava through the Curie-point of the ferromagnetic minerals in the rocks, affected by the earth's magnetic field, in which case the direction of natural remanent magnetization of An'ei lava must agree with the direction of the earth's magnetic force in 1778. The mean value of $\Delta\delta$ and dip of the samples of An'ei lava are 5·0° East±1·8° and 48°±2° respectively, while those of the Meizi-Taisyo lava are 0·3° West±1·1° and 49°±1°.

From studies of secular variation in magnetic declination in Japan made by members of the Hydrographic Department of the Japanese Navy[7], the declination at Ogiura in the Ogasawara Islands (800 km South of Oosima Island) was 1°08′ East in 1827, and probably 3.5° East in 1800, while it was 2°47.1′ West in 1933. Since the secular change in declination in the vicinity of Volcano Mihara, Oosima Island, is almost the same as that in Ogasawara, the magnetic meridian in Oosima in 1778 would have been also 5 or 6 degrees East of the present meridian.

The deviation in the case of determining the direction of the natural remanent magnetization of the An'ei (1778) lava from a large number of samples, is of the same order of magnitude as the mean errors, so that we cannot be very positive of the results. However, qualitatively speaking, that the magnetic meridian at Oosima, in 1778, was about 5 degrees East of the present magnetic meridian may be seen from the result mentioned in the preceding paragraph.

As given in Table I, the specific intensity of the natural remanent magnetization J_{rn} is very large compared with the induced magnetism in the earth's magnetic field, i. e., the product of specific susceptibility and the total intensity of the earth's magnetic force. The characteristic quantity $Q_n = J_{rn}/K_0H$, which was defined by J. G. Königsberger[8], is given in Table I. The values of the thermo-remanent magnetization J_{rt} of several samples, which were obtained by quenching from 800°C to 20°C in a magnetic field of 0·26 Gauss, are given in Table II. Although the intensity of the thermo-remanent magnetization, obtained by rapid cooling in the laboratory, is less than the intensity of natural magnetization, the former is still very large compared with the induced magnetism. We may therefore conclude that the natural remanent magnetization of Mihara lava is the result of slow cooling of the earth's magnetic field from a state of high temperature. The results of more

6) R. TAKAHASI and T. NAGATA, *Bull. Earthq. Res. Inst.*, 15 (1937) 443.
7) S. KUWABARA, *Bull. Hydro. Dep. Japanese Navy.*, 8 (1936).
8) J. G. KÖNIGSBERGER, *Beitr. Angew. Geophys.*, 5 (1935), 193.

systematic study on thermo-remanent magnetization of the ejecta of Volcano Mihara and other volcanoes in Japan will be reported in the near future.

Table II.

No of Samples	Curie-point	J_{rt}/ρ
3	$490\pm10°$	$10{\cdot}1\times10^{-3}$
5	$520\pm10°$	$10{\cdot}9\times10^{-3}$
6	$500\pm10°$	$5{\cdot}4\times10^{-3}$
8	$485\pm10°$	$8{\cdot}2\times10^{-3}$
9	$520\pm10°$	$13{\cdot}3\times10^{-3}$
11	$420\pm10°$	$7{\cdot}2\times10^{-3}$

5. The foregoing results show that the direction of the natural remanent magnetization is nearly equal to the direction of the present geomagnetic force, and that the specific intensity is 0·017–0·036, whence it may be said that the anomalous distribution of geomagnetic declination around the crater of Volcano Mihara is due to both induced magnetism and the remanent magnetization. The mean values of the specific susceptibility and the remanent magnetization are $6{\cdot}5\times10^{-4}$ and 0·025 respectively, while the mean susceptibility, as expected from the results of magnetic survey, was 0·013, (i. e., the intensity of magnetization is 0·0059). The first is too small and the second is too large compared with the last value. The central cone of Mihara, however, is formed not only of continuous unbroken ropy lava, but also of bombs, lapilli, ash, and other pyroclastic material. If we assume that a lava sheet, 6 or 7 *m* thick, with natural remanent magnetization, covers the body of the central cone composed of pyroclastic ejectamenta that have a magnetic susceptibility almost the same as that of the lava, but without any remanent magnetization in the sense of average or mean character of the whole body, the interpretation of the magnetic survey is in good agreement with the results of experimental studies on the magnetic properties of rocks. The construction just assumed is reliable, seeing that it is visible on the inner wall of the central cone.

6. This short note is a preliminary report on the natural remanent magnetization of volcanic rocks in Japan. The relation between the intensity of thermo-remanent magnetization, the temperature of the Curie-point, the temperature coefficient of magnetic susceptibility, etc., of the rocks and their petrographic and chemical constitutions will be reported in a following paper.

In conclusion, the writer tenders his sincere thanks to Prof. K. Sezawa, Dr. C. Tsuboi, Dr. H. Tsuya and Dr. R. Takahasi for their interest and encouragement in the present work. His hearty thanks are also due to Prof. M. Matuyama, Kyôto Imperial University, for his encouragement and many valuable advices.

14. 三原火山中央火口丘熔岩の自然殘留磁氣

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三原火山の中央火口丘噴出物の中，安永熔岩及び明治大正熔岩から採集した標本11個に就いて，その自然殘留磁氣の強さと方向とを測定した．之等の標本は熔岩が凝固してから後は殆んど全く動いてゐないと見られる縄狀熔岩流の中から，自然狀態に於ける方向を測定して採集されたものである．測定裝置は無定位磁力計により，岩石標本の重心を通る總ての方向での磁氣能率の成分を測定してその帶磁の强さと方向とを測定した．實際の測定には 20° 毎の異れる角度に於いて測定し，又帶磁の方向の決定に際しては，必要な場合には中村淸二博士，松山基範博士の採用された Gauss の方法によつて分析を行つた．斯様な測定の結果安永熔岩の自然殘留磁氣の强さは 0·025±0·006 でありその方向は伏角が 48°±2°，偏角は現在の磁氣子午線より 5·0°±1·8° 東に傾いてゐるし，明治大正熔岩は强さが 0·018±0·001 であり，方向は伏角が 49°±1° 偏角は現在の磁氣子午線に對して 0·3°±1·1° 西偏である．

概して云へば，之等の帶磁の方向は現在の三原山附近の地球磁氣の方向と一致し，又實驗室に於いて 0·26 ガウスに於ける熱殘留磁氣を測定した結果と對比しても，三原熔岩の自然殘留磁氣は熔岩が地球磁場に於いて高溫狀態から冷却する際に 500°C 附近に於いて生じた熱殘留磁氣と解する事が出來る．

安永熔岩の帶磁の方向が現在の磁氣子午線より 5° 東に偏つてゐるといふ結果はその平均誤差の大いさと同程度なので信用度は低いけれども，小笠原島に於いて 1800 年頃は磁氣子午線が現在に比して約 6° 東偏してゐたといふ事實に比べて少くともその傾向は一致してゐると云へよう．

三原火口附近に於ける地磁氣異常は中央火口丘を構成する岩層の地球磁力による誘導磁氣と，その上を蔽ふ熔岩流の自然殘留磁氣及び誘導磁氣に因ると解すれば，熔岩流の厚みが數 m 乃至 10 m となつて實際の狀態と良く一致する．