3. *Geomagnetic Studies of Volcano Mihara.* *The 4th paper.* (*A Series of Geomagnetic Dip-Surveys and Continuous Observation of Changes in Geomagnetic Declination.*)

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1. Introduction.

Since the 1950 eruption of Volcano Mihara in Ooshima Island, the writer has been carrying on geomagnetic studies there. As has been already reported in a series of papers[1][2][3], the remarkable changes in geomagnetic dip that accompanied the earlier stage of the eruptions as well as some plausible changes in geomagnetic declination associated with the volcanic activities were observed. The former was detected by a series of dip-surveys with a miniature earth-inductor[4] and the latter by continuous recording of declination at a temporary station situated on the western foot of the volcano.

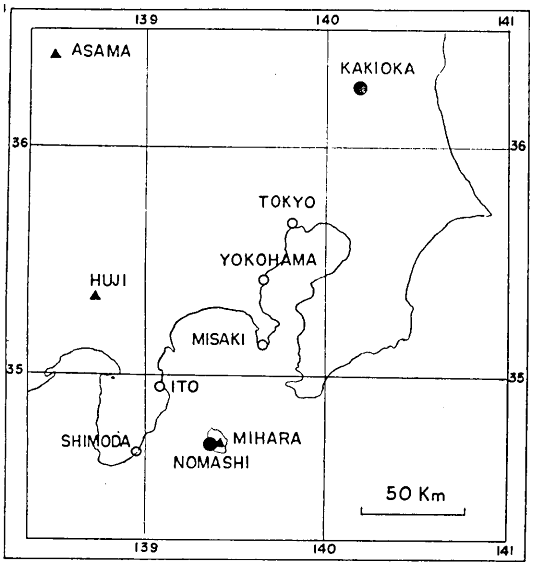

Fig. 1. Geographical position of Ooshima Island.

It has become evident that, as far as volcanoes composed of basaltic rocks are concerned, some anomalous changes in the earth's magnetic field occur in relation to volcanic

1) T. RIKITAKE, *Bull, Earthq. Res. Inst.*, **29** (1951), 161.
2) T. RIKITAKE, *Bull. Earthq. Res. Inst.*, **29** (1951), 499.
3) T. RIKITAKE, I. YOKOYAMA, A. OKADA and Y. HISHIYAMA, *Bull. Earthq. Res. Inst.*, **29** (1951), 583.
4) T. RIKITAKE, *Bull. Earthq. Res. Inst.*, **29** (1951), 147.

eruptions as proved by the studies on the 1950 eruption of Volcano Mihara. Although the each result slightly differed one another, we have another similar evidence in the case of the 1940 eruption of Volcano Miyake-Shima[5)6)7)8)]. In order to bring out geomagnetic changes of this kind more clearly, the writer had been trying to carry out geomagnetic surveys and observations as accurately as possible. As a result, we could accumlate the geomagnetic data in regard to the various periods of the activities of Volcano Mihara. On the basis of these data, the writer would like to discuss the relation between changes in geomagnetic field and volcanic activities in this paper. The interpretations conjectured by analyzing the results will be discussed in the next report.

2. The activities of Volcano Mihara and geomagnetic surveys by Oct. 1953.

The activities of Volcano Mihara from July 1950 to Oct. 1953 are briefly summarized in Table I.

The magnetic dip-surveys I, II, III and V were carried out with a miniature dip-inductor. The surveys IV, VI and VII and the absolute measurements of three geomagnetic elements in order to check the base-line value of the declination-variometer at the temporary station at Nomashi Village were made with G.S.I. type magnetometers. The sensibilities of these instruments are standardized to the Kakioka Magnetic Observatory and tabulated in Table II.

The results of the dip surveys I, II and III were already shown and fully discussed in the preceding reports[9)10)] by T. Rikitake. As some stations were buried under the newly overflowed lava and some have suffered from artificial changes in the surroundings, the number of the stations available for the present study has decreased in these three years. The observed values of dip-angle in all surveys in Ooshima from July 1950, are shown in Table III, where the differences between the values of dip at Ooshima and Kakioka are also shown in order to eliminate the influences of the geomagnetic disturbances and daily

5) R. TAKAHASHI and K. HIRANO, *Bull. Earthq. Res. Inst.*, **19** (1941), 82 and 373.
6) T. MINAKAMI, *Bull. Earthq. Res. Inst.*, **19** (1941), 356.
7) T. NAGATA, *Bull. Earthq. Res. Inst.*, **19** (1941), 335.
8) Y. KATO, *Proc. Imp. Acad. Japan*, **16** (1940), 440.
9) I. TSUBOKAWA, General Discription of a New Type Magnetometer (1949).
10) I. YOKOYAMA, *Bull. Earthq. Res. Inst.*, **31** (1953), 211.

Table I. The activities of Volcano Mihara from July 1950 to Oct. 1953.

Date	Activities	Magnetic surveys
1950		
July 16	Eruption commenced.	
25	Depth of ejected lava in the old pit reached to 30m.	I (Dip survey)
Aug. 15	Lava filled up the old pit.	
Sept. 12	Lava filled up the inner somma.	
23	Eruption stopped.	II (Dip survey)
The mass of the ejected lava amounted to about 4×10^7 *metric tons*.		
1951		
Feb. 4	Eruption relapsed.	
28	Lava overflowed the inner somma.	
Mar. 17	Lava-flow reached to the outer somma.	
24	Lava-fountain appeared.	III (Dip survey)
Apr. 1	Eruption stopped.	Continuous observation of geomagnetic declination was begun.
Apr. 16 ~ 29		
May 1 ~ 7	Pyroxysmal eruption.	IV (Survey of three geomagnetic elements)
June 9 ~ 27		
June 30	Eruption ended.	
The mass of the ejected lava totaled to about 7×10^7 *metric tons*.		
July 10		Absolute measurement of declination.
Nov. 9		
1952		
Jan. 19		〃
May 9		〃
1953		
Feb. 27		〃
Mar. 27		V (Dip survey)
August		VI (Surevy of three geomagnetic elements)
Oct. 5	Minor eruption commenced.	
Oct. 8		VII (〃)

Table II. Sensibilities of the instruments.

	Declination	Horizontal Intensity	Inclination
Miniature Dip-inductor[4] (I, II, III, V)	—	—	1′
G.S.I. First Order Magnetometer[9] — Trial Machine — (IV)	0′.14	2.3γ	0′.21
G.S.I. Second Order Magnetometer[10] (VI, VII)	0′.20	1.5γ	0′.15

variation. In Table III, the station No. 5 (bench mark point for the leveling survey on the central cone) which lies within a distance of about 5 *meters* from the front of the 1951 lava showed a remarkable change in dip-angle as much as 4 *degrees* during the period from II to V. On the station No. 33 (the Nomashi pass on the first somma), the change amounted to about 20 *minutes* of arc. This may be presumably ascribed

Table III.

Dip-angle (Ooshima)

Dip-surveys / Nos. of station	I 1950 July	II 1950 Sept.	III 1951 March	IV 1951 May	V 1953 March	VI 1953 August	VII 1953 Oct.
4	51° 33′.3	51° 18′.6	51° 16′.4		51° 28′.5		
5	56 26.6	56 07.0			52 07.2		51° 59′.4
7	53 57.0	53 34.2	53 30.4		53 39.4		
14	48 34.6	48 24.4	48 23.8	48° 22′.5	48 17.8	48° 19′.0	
16	48 36.9	48 37.1	48 36.0	48 37.7	48 32.0	48 33.2	
19	48 13.8	48 10.3	48 08.8	48 13.7	48 03.2	48 07.6	
24	47 40.3	47 28.6	47 25.4	47 18.6	47 20.0	47 21.1	
26	47 02.3	46 59.5	46 57.5	46 57.0	46 57.0	46 53.4	
28	48 26.5	48 22.5	48 18.9		48 26.0		
33	51 44.4	51 27.2	51 23.9		51 41.2		
37			47 19.1	47 22.0	47 21.2	47 22.0	47 19.3
38				49 28.4	49 22.3	49 21.7	
39				52 16.2	52 13.5	52 11.4	52 10.0
40				50 40.8	50 40.0	50 41.0	
41				48 23.7	48 26.0	48 19.6	
42						47 29.8	47 28.4

Differences in Dip-angle (Ooshima–Kakioka)

Dip-surveys / Nos. of station	I 1950 July	II 1950 Sept.	III 1951 March	IV 1951 May	V 1953 March	VI 1953 August	VII 1953 Oct.
4	2° 08′.1	1° 52′.6	1° 50′.0		2° 06′.1		
5	7 00.1	4 41.5			2 43.9		2° 39′.4
7	4 28.6	4 08.5	4 06.3		4 16.2		
14	– 51.2	−1 01.2	−1 01.1	−1° 02′.7	−1 03.4	−1° 03′.2	
16	– 48.7	– 48.7	– 48.3	– 48.0	– 49.2	– 48.7	
19	−1 10.7	−1 16.6	−1 15.6	−1 12.8	−1 19.5	−1 13.9	
24	−1 44.5	−1 58.3	−1 58.4	−2 05.0	−2 02.5	−2 03.3	
26	−2 21.3	−1 25.4	−2 26.5	−2 27.3	−2 24.1	−2 27.9	
28	– 56.8	−1 02.6	−1 04.8		– 57.0		
33	2 20.3	2 00.6	1 59.2		2 18.2		
37			−2 05.0	−2 00.6	−2 02.3	−1 59.9	−2 02.1
38				04.0	– 0.2	0.6	
39				2 52.0	2 50.8	2 52.7	2 49.5
40				1 14.9	1 16.6	1 15.3	
41				−1 01.2	– 57.0	−1 00.9	
42						−1 51.8	−1 53.5

to the stone-wall which was constructed to stop the lava-flow[11].

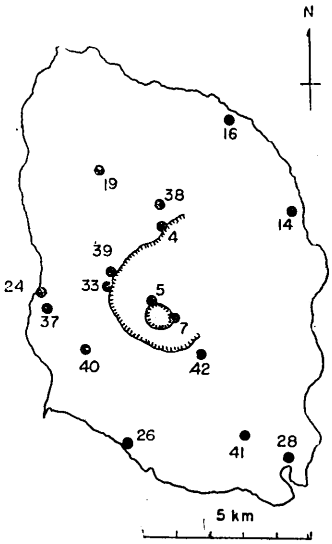

Fig. 2. Positions of the geomagnetic stations.

Nos. of station	Locality	
4	岡田登山道十合目	First somma
5	内輪山水準点	Central cone
7	内輪山最高点	Highest point of central cone
14	動物園	Zoo
16	泉津小学校	Senzu primary school
19	大島測候所	Ooshima Meteorol. Station
24	野増村緑地	Nomashi village
26	間伏	Mabushi
28	波浮港小学校	Habukō primary school
33	野増口峠	Nomashi pass
37	眞坂邸	Mr. Masaka's garden
38	湯場	Yuba
39	御神火茶屋	Gojinka-chaya
40	滑り台	Suberidai
41	差木地，余川	Sashikiji, Yokawa
42	白石山南方	Shiraishi-yama

3. The effects of the ejected lava-flow upon the geomagnetic field.

Since the cooled lava have intense magnetization, it is important to eliminate the magnetic field caused by the lava-flows in order to presume the interior of the volcano from the changes in geomagnetic field. Following the outbreak of the activity in July 16, 1950, lava filled up the central pit by Aug. 15 and then flowed down the slope to the caldera. The amount of the lava which welled up during the period of activity in 1950 totaled to about 4×10^7 *metric tons*. On Feb. 4, next year, the volcano recovered its activity in a large scale and the overflowed lava reached the inside wall of the first somma on Mar. 17. The total amount of the lava which welled up in these two years was estimated as much as 7×10^7 *metric tons*.

If we assume an uniform magnetization, Poisson's theorem gives

$$V=\frac{J}{G\sigma}\frac{\partial U}{\partial i},$$

11) A. C. MASON and H. L. FOSTER, *American Journal of Science*, **25** (1953), 249.

where V is the magnetic potential, J the intensity of remanent magnetization, G the gravitational constant, σ density, U the gravity potential, and i the direction of magnetization. With the aid of this relation, the effects of the ejected lava-flow upon the geomagnetic field at the respective stations are roughly estimated assuming that $J=5\times10^{-2}$ *e.m.u.* per *cubic centimeter*[12] and $i=53$ *degrees* (geomagnetic dip-angle in

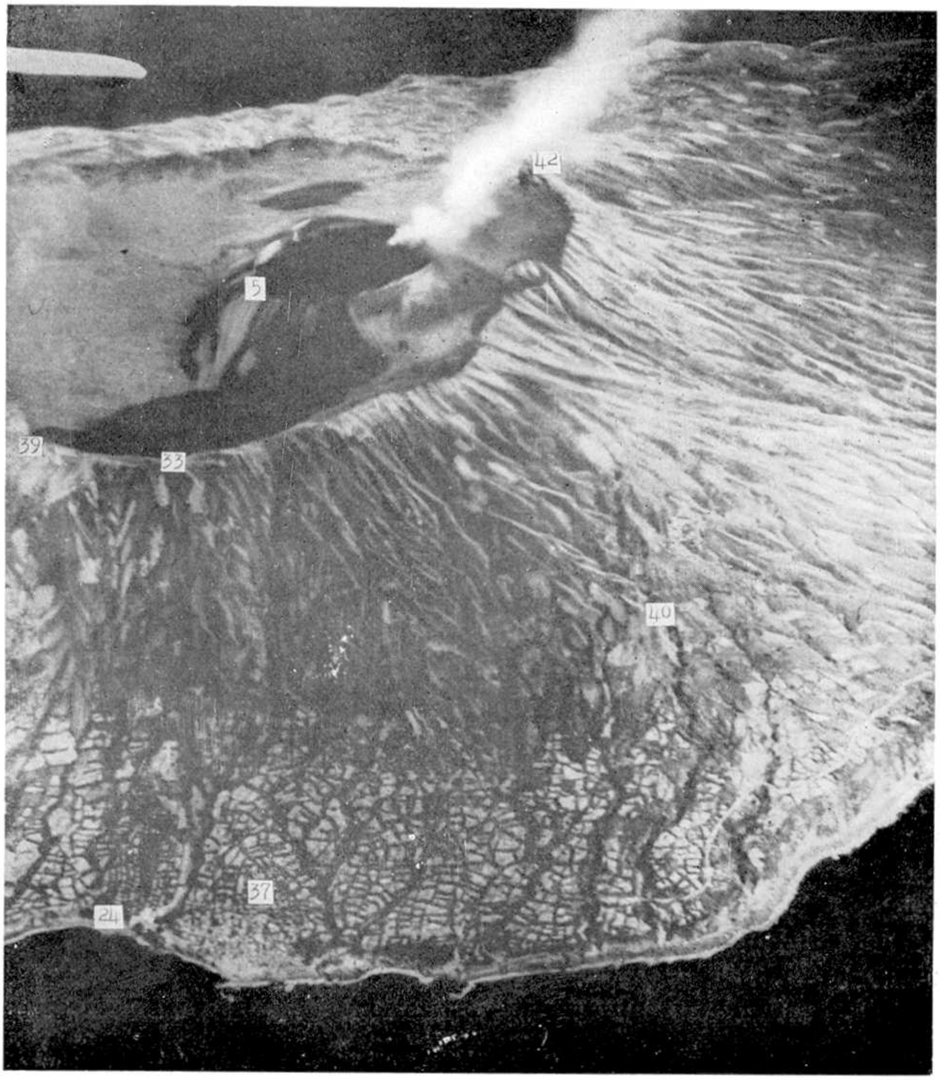

Fig. 3. Scene of the overflowed lava on Mar. 23, 1951 and distribution of geomagnetic stations. Photographed by T. YOSHIDA, Yomiuri Shimbun.

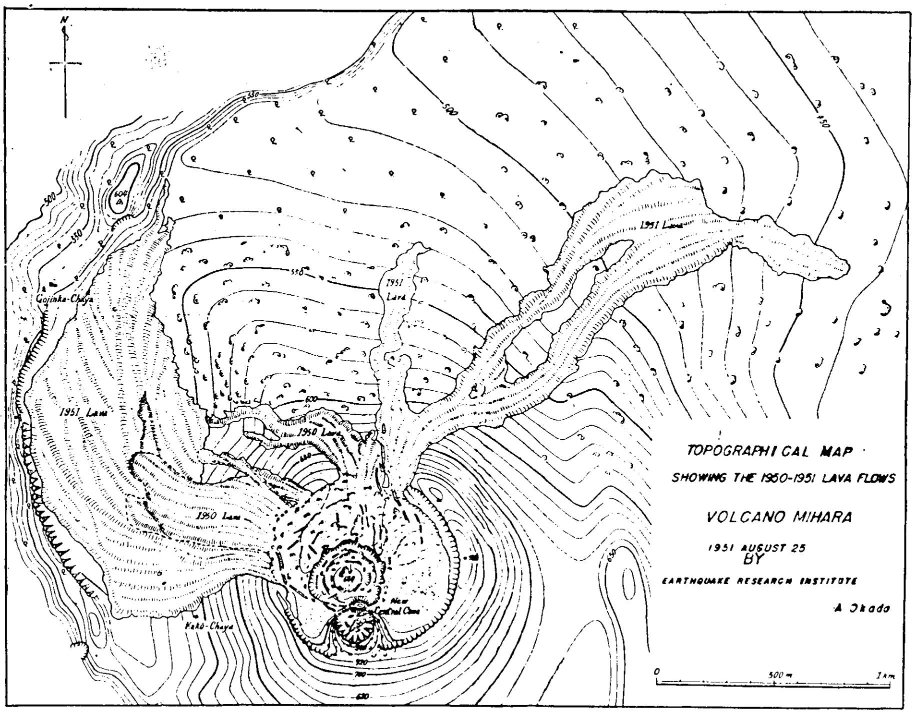

Fig. 4.

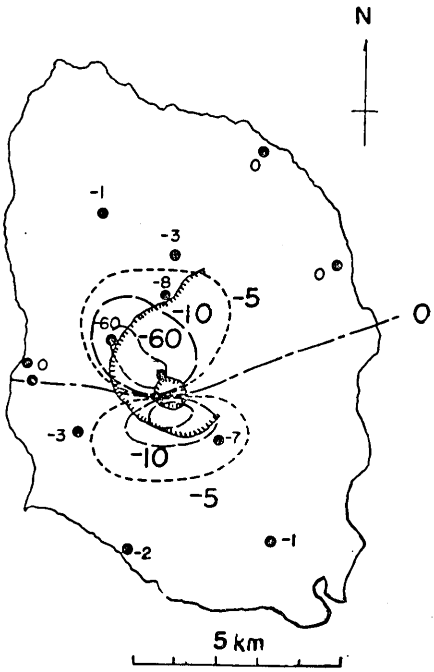

Fig. 5.
The effects of the ejected lava in dip-angle. The unit is *minute* of arc.

the neighborhood of the central cone of the volcano). The gravity gradients and curvature values are obtained by the usual graphical method in Fig. 4 where the station No. 39 (Gojinka-chaya) is so close to the lava-flow that the result is only a rough estimation. The effects of the ejected lava-flow at each station are thus roughly estimated and converted into dip-angle as shown in Fig. 5.

4. Changes in magnetic dip during the period from July 1950 to Oct. 1953.

By referring to Table III, the succesive time-variation of the difference-values in dip-angle, from which the influences of magnetic storms and daily variations are corrected with the aid of the values at Kakioka, are shown in Figs. 6–11. The unit is *minute* of arc in these figures.

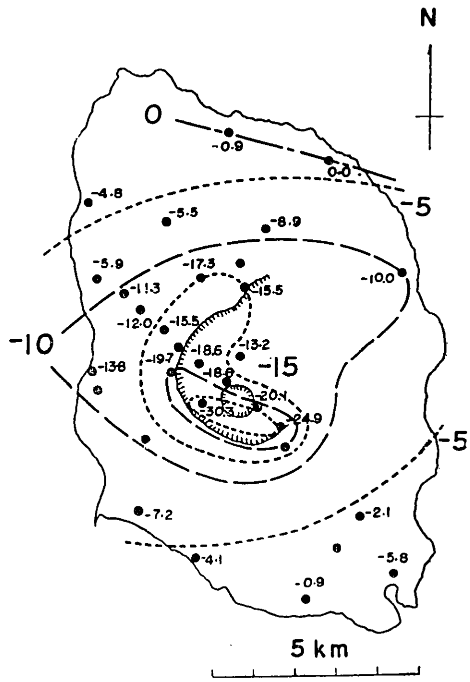

Fig. 6. Changes in geomagnetic dip II Sept. 1950—I July 1950.

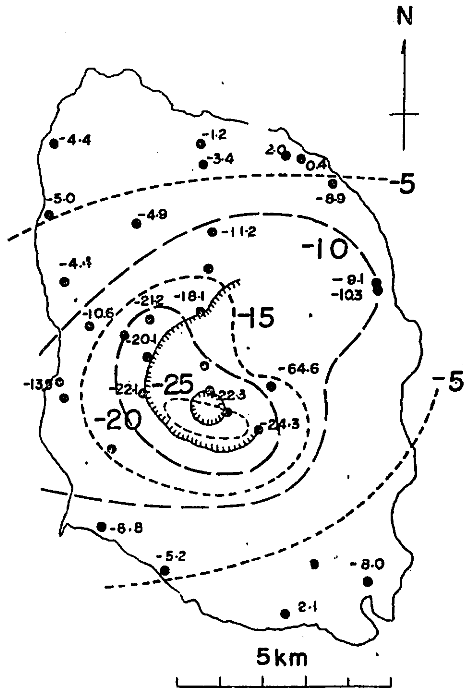

Fig. 7. Changes in geomagnetic dip III Mar. 1951—I July 1950.

12) T. NAGATA, *Journal of Geography* (*Tokyo*), **60** (1951), 44.

Since the difference of general secular changes of dip-angle between Ooshima and Kakioka amounts to about 0.22 *minute* of arc per year for 1950.0, the corrections for this difference are taken into account in the case of (VI Aug. 1953–IV May 1951) where the accuracies of both observations were very high and the time interval was more than two years. Moreover, the effect of the ejected lava-flow is eliminated in the cases of (V Mar. 1953–I July 1950), (VI Aug. 1953–I July 1950) and (V Mar. 1953–III Mar. 1951).

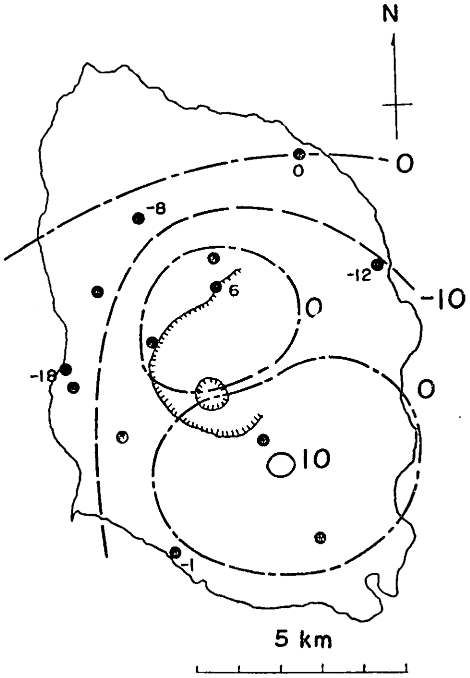

Fig. 8. Changes in geomagnetic dip V Mar. 1953—I July 1950 (the effects of ejected lava are corrected).

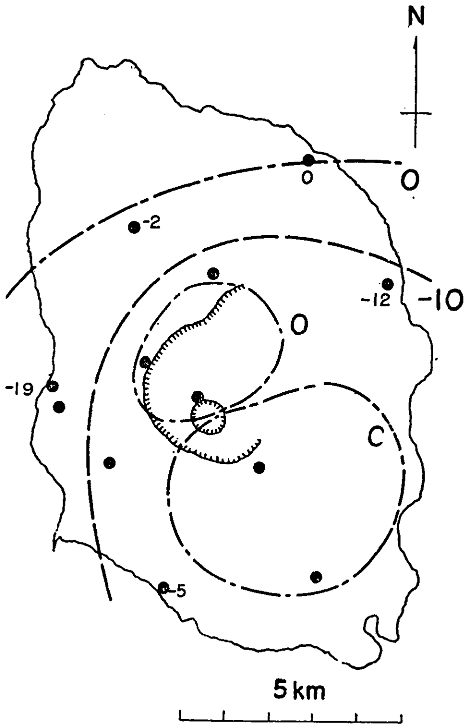

Fig. 9. Changes in geomagnetic dip VI Aug. 1953—I July 1950 (the effects of ejected lava are corrected).

The anomalous changes accompanying (II Sept. 1950–I July 1950) were fully discussed in the 2nd paper by Rikitake who concluded that the changes seem to be explained by the apparent demagnetization of a roughly spherical region of which the centre is situated at a depth of about 5 *km* and the mean radius is about 2 *km*. In other words, it was interpreted that the above-mentioned region may be presumed to have lost its magnetic property owing to the rise in temperature associated with the eruption.

Comparing Figs. 8 (V–I) and 9 (VI–I) to Figs. 6 (II–I) or 7 (III–I), anomalous changes in dip-angle that accompanied the eruption in 1950 seem to have been almost recovered by 1953. Although the distribution of changes in geomagnetic field in the central region is not clear owing to the magnetic disturbances due to the overflowed lava, it seems likely that the recovering changes exceed the earlier ones at some stations.

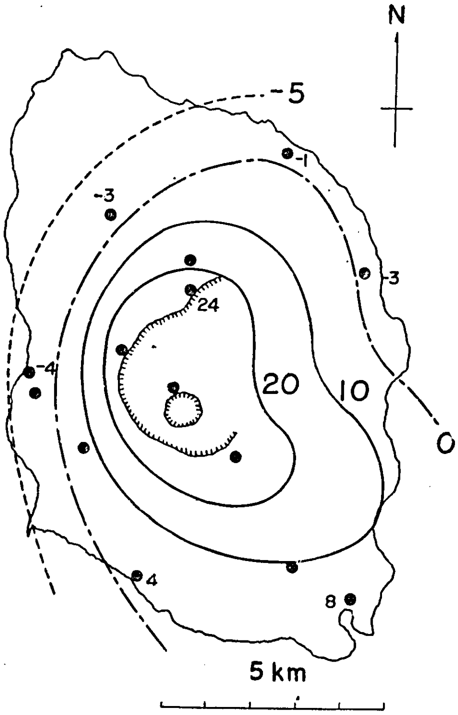

Fig. 10. Changes in geomagnetic dip V Mar. 1953—III Mar. 1951 (the effects of ejected lava are corrected).

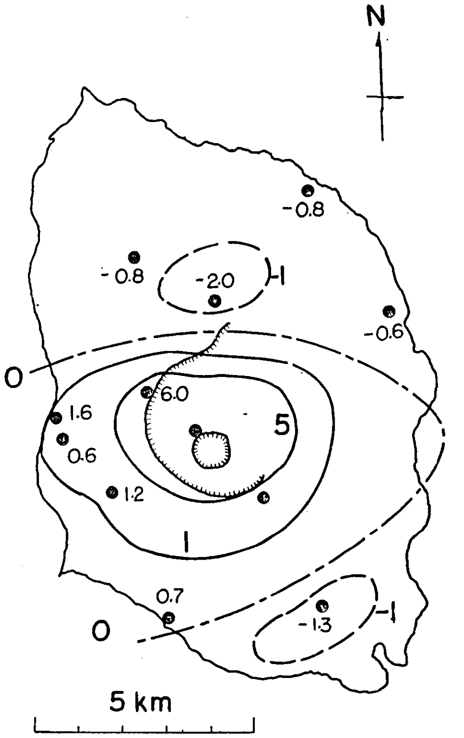

Fig. 11. Changes in geomagnetic dip VI Aug. 1953—IV May 1951 (secular variation and the effects of ejected lava are corrected.)

Survey VII was carried out on Oct. 8 and 9, 1953 for the purpose of detecting the change accompanying the minor activity that abruptly occurred on Oct. 5 after about two years' quiescence. The survey was made on the stations near the central cone with G.S.I. type magnetometer, the accuracy of the measurements being 0.1 *minute* of arc. As shown in Fig. 12, concentric distribution of decrease in dip-angle amounted to more than 3 *minutes* of arc during the period from August to October. This decrease may be ascribed to the minor activity of the volcano. Since the new activity is intermittent pyroxysmal eruption in

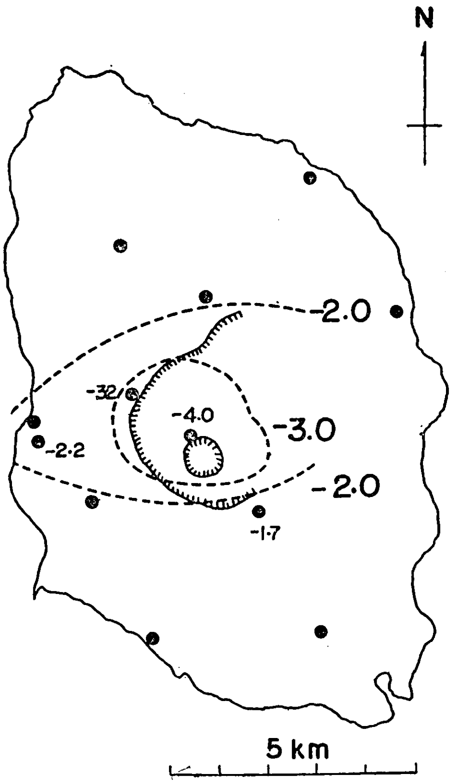

Fig. 12.

Changes in geomagnetic dip accompanied by the minor eruption in Oct. 1953 (VII Oct. 1953 —VI Aug. 1953). The unit is *minute* of arc.

a minor scale, it seems natural that we got smaller changes in geomagnetic field than those of the earlier and more violent stage of the 1950 eruption.

5. Some results of the continuous observation of changes in geomagnetic declination at the temporary station.

As already reported in the 3rd paper, since April 1951, the writer has continuously recorded the changes in geomagnetic declination with a variometer at the temporary station (No. 37) on the western foot of the volcano, about 4 *km* distant from the crater.

The 15-day means of the westerly declination at Ooshima and Kakioka are shown in Fig. 13. For the purpose of showing the gradual time-variation of the declination, the 15-day means are convenient. The mean values are calculated from daily means obtained by averaging hourly values. In order to check the base-line value of the variometer,

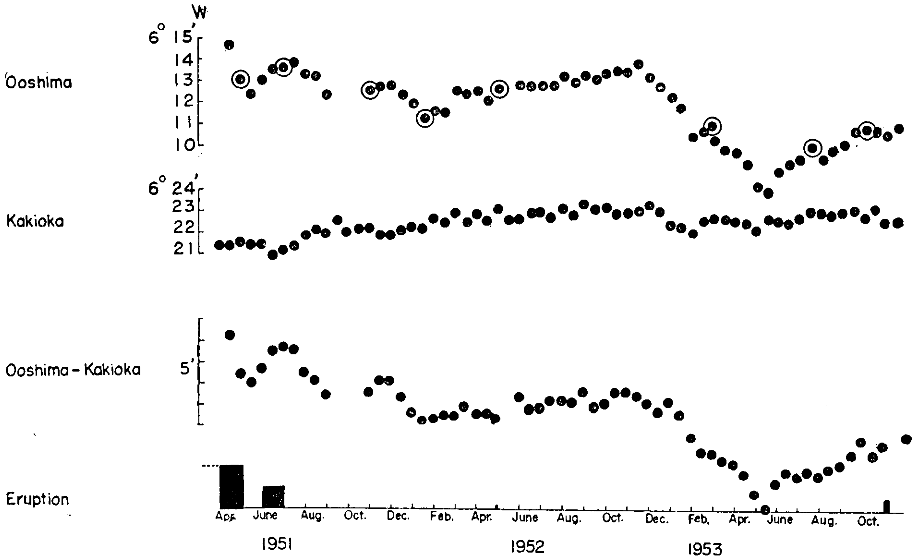

Fig. 13. The 15-day means of the westerly declination at Ooshima and Kakioka.

a series of absolute measurements of declination has been carried out in front of the variometer-room, the results of which are shown in Fig. 13 with large hollow circles and in Table IV including the other elements. In order to express the changes which may be presumed to be related with activities of the volcano more clearly, the differences between the values of the declination at Ooshima and Kakioka are also plotted together with the period during which the eruption continued. As already stated in the 3rd paper, an increase in the westerly declination was observed just before the active period in June 1951, which was the finale of the 1951 eruption. Meanwhile the westerly declination showed again a decrease which followed the said maximum and another maximum was observed in December 1951. Although no active eruption took place at that time, some topographical change occurred at the bottom of the new pit and micro-tremors of large amplitude were observed by seismometers. As may be seen in the figure, the differences between both stations increased gradually in 1952 in spite of the gradient of opposite sign in the differences of geomagnetic secular variations which amount to respectively 2.00 and 2.27 *minutes*

Table IV. Results of absolute measurements at the station No. 37, Nomashi Village.

Time (J.S.T.)	D	I
1951 Nov. 8		
14*h* 36*m*	6° 16′.7	47° 30′.9
15 54	15.5	29.5
18 04	13.0	26.0
Nov. 9		
09 08	11.3	26.7
10 08	12.0	25.9
11 06	12.1	24.2
11 50	14.1	24.4
Mean	6° 13′.5	47° 26′.8

Time (J.S.T.)	H
1951 Nov. 9	
10*h* 21*m*	30010γ
11 18	30020
Mean	30015γ

Time	D	I
1952 Jan. 19		
12*h* 08*m*	6° 11′.8	47° 24′.2
13 07	12.4	24.6
14 08	12.0	24.5
15 06	11.6	24.1
16 18	10.9	24.5
17 10	11.0	24.4
18 00	10.4	24.4
19 26	11.1	24.3
21 08	10.7	24.2
Jan. 20		
01 20	10.5	24.5
04 10	11.3	24.0
08 10	10.0	23.5
09 20	8.7	23.4
10 48	8.9	24.2
Mean	6° 10′.8	47° 24′.3

Time	H
1952 Jan. 19	
11*h* 30*m*	29991γ
13 22	30016
14 08	30026
16 20	30016
21 08	30001
Jan. 20	
10 08	30008
Mean	30010γ

Time	D	I
1952 May 8		
16*h* 29*m*	6° 14′.4	47° 25′.4
17 58	14.9	25.2
18 38	13.9	25.2
20 35	12.6	25.0
22 38	12.0	24.7
23 34	10.8	24.8
May 9		
01 08	7.9	24.5
01 52	7.5	25.2
02 35	7.9	25.2
10 34	14.3	25.0
11 06	14.8	24.4
11 34	15.5	24.7
12 06	16.0	24.0
12 36	16.2	23.9
Mean	6° 12′.8	47° 24′.8

Time	H
1952 May 8	
16*h* 44*m*	29987γ
18 06	29991
18 48	30019
20 46	30003
23 48	30012
May 9	
01 20	30007
02 08	30002
Mean	30003γ

(to be continued.)

Table IV. (Continued.)

Time (J.S.T.)	D	I
1953 Feb. 27		
09*h* 13*m*	6° 10′.4	47° 23′.0
10 31	11.6	22.0
11 34	14.0	20.2
12 14	13.9	21.6
13 18	14.3	22.1
14 28	13.0	20.9
15 31	12.0	22.4
18 51	9.6	22.9
20 50	6.8	23.0
22 02	10.2	23.0
23 32	9.6	22.1
Feb. 28		
04 46	8.9	23.0
06 55	10.5	23.2
10 05	8.1	23.9
Mean	6° 10′.9	47° 23′.2

Time (J.S.T.)	H
1953 Feb. 27	
10*h* 46*m*	30006γ
17 59	30012
Mean	30009γ

Time	D	H	I
1953 July 30∼31			
08*h* 56*m*	6° 10′.5		47° 21′.2
10 12	9.9		21.4
12 42	14.2		20.6
14 12	14.7		25.9
16 10	13.2		23.4
17 46	11.3		23.6
18 30	10.4		23.3
21 04	6.9		21.4
21 34	9.7		21.7
07 05	7.8		21.7
07 53	8.8	29995γ	22.7
09 18	9.9	29996	21.9
10 10	—	29991	21.5
10 52	10.2	29991	20.7
11 36	11.4	29987	22.0
Mean	6° 10′.6	29992γ	47° 22′.0

Time	D	H	I
1953 Oct. 8			
21*h* 14*m*	6° 11′.4	30044γ	47° 20′.0
22 04	11.1	30041	19.9
22 24	10.8	30045	19.7
22 44	10.6	30045	19.5
Oct. 9			
08 55	7.9		
10 05			19.8
10 53	10.7		19.3
11 05	11.6		19.3
12 11	13.1		19.0
12 32	13.7		19.0
14 59	11.3		18.6
15 08	11.8		18.5
16 15	9.9	30048	19.2
Mean	6° 11′.2	30045γ	47° 19′.3

of arc westerly per year. According to the reports of the Ooshima Meteorological Station, on Sept. 18, 1952 a fissure appeared at the

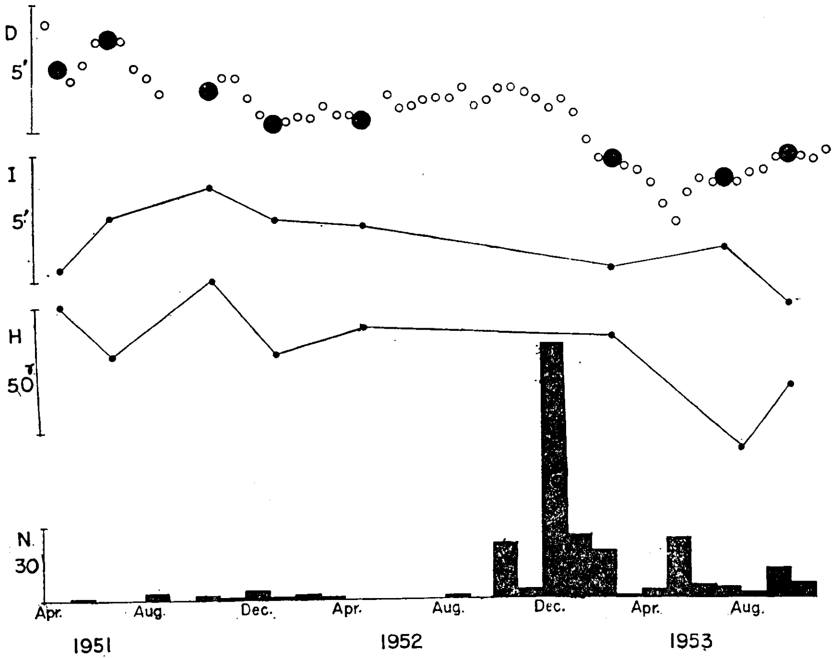

Fig. 14. Changes in three geomagnetic components (Ooshima-Kakioka) at the Nomashi Station (No. 37). Lowest column shows the number of the earthquake observed by the Ooshima Meteorological Station of which PS-time is shorter than 5 *seconds*.

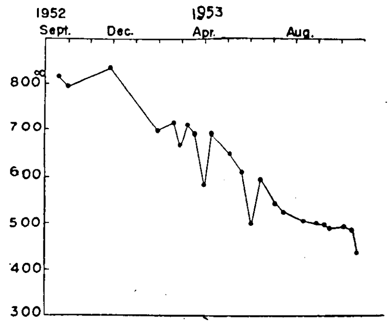

Fig. 15. Cooling curve of a fissure in the inner somma. (After Ooshima Meteorological Station)

1951 lava-flow in the inner somma and its temperature was measured at 817°C. This temperature reached the highest 840°C in December and then began to decrease as shown in Fig. 15. The westerly declination showed a remarkable minimum in May 1953, and recovery towards October, while the crater of the volcano continued to emit only water vapour of small amount after the last eruption in June 1951. It is noticeable that the increase of the westerly declination coincides with the abrupt minor eruption on Oct. 5. Fig. 14 shows the changes in the differences between both stations in horizontal intensity and inclination obtained by a series of absolute measurements and the number of the earthquakes observed by the Ooshima Meteorological Station of which PS-time is shorter than 5 *seconds*.

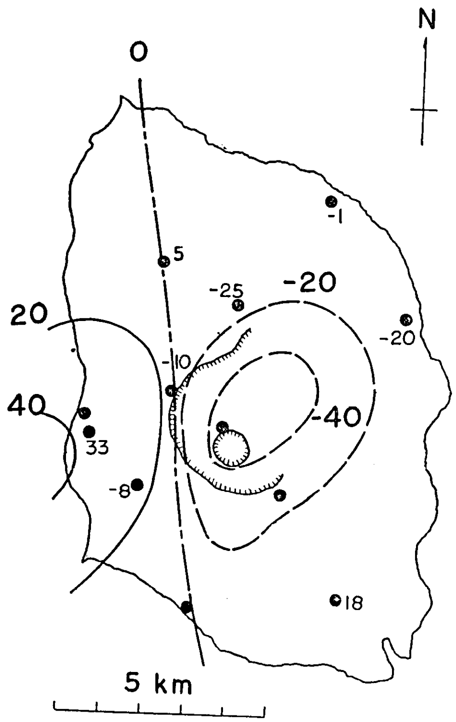

Fig. 16. The changes in geomagnetic east-component from May 1951 to Aug. 1953 (secular variation and the effects of ejected lava are corrected). The unit is *gamma*.

To examine the general tendency in the changes of declination all over the island, the differences of values in declination at the stations where the three-elements survey IV was carried out in May 1951, are obtained by repeating similar measurements VI in Aug. 1953, as shown in Fig. 16 (refer to the next report). Comparing this chart with the distribution of the declination shown in Fig. 4 of the 3rd paper, it seems likely that the decrease in the westerly declination may correspond to the increase of the magnetization of the under-ground mass and *vice versa*. However, much more data should be accumlated in order to infer the internal condition of the volcano from geomagnetic changes observed on it.

6. Summary and conclusion.

Succeeding to the 3rd paper, the writer reported the results obtained by the subsequent surveys and observations in this paper. By a series of dip-surveys, the recovery of the local anomalous changes which accompanied the 1950 eruption was detected. According to the results obtained by the continuous observation of declination at the temporary station, it was observed that there were decreases and increases of declination relating to the volcanic activities. This change is compatible with those of declination observed at various stations during the period from May 1951 to Aug. 1953 as shown in Fig. 16. The characteristic changes in both declination and dip were also confirmed on the occasion of the minor eruption in Oct. 1953. Detailed interpretations conjectured by analyzing the results will be given in the future reports.

In concluding, the writer wishes to express his hearty thanks to Dr. T. Rikitake for his helpful advices, who initiated this study and is now staying in England. To Prof. T. Nagata for his helpful criticism and encouragement, the writer's cordial thanks are also due. The writer's hearty thanks are also due to Mr. T. Yoshimatsu of the Kakioka Magnetic Observatory and Mr. T. Yokoyama of the Ooshima Meteorological Station who placed valuable data at the writer's disposal. Mr. A. Okada assisted the writer in field works, to whom the writer's cordial thanks are also due. The writer wishes to express his sincere thanks to Messrs. T. Masaka, T. Yanai and S. Saito and Miss Y. Hishiyama who assisted the writer in the course of study.

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3. 三原山の地球磁気学的研究 第4報 (一連の伏角測量と偏角変化の連続観測)

地震研究所 横 山 泉

三原山の1950年の噴火以来，地球磁場の変動を出来る限りの高い精度で，しかも長期にわたつて観測し，その資料を集めるよう努力してきたが，第3報に続いて，1953年10月までに行われた一連の伏角測量と偏角変化の連続観測との結果をとりまとめて報告した．地磁気変化と火山活動との関係を吟味すると，推論は当然，地下の状態に及ぶのであるが，そのためには火口から溢出した熔岩の磁気的効果を考慮せねばならぬ．4回にわたる全島伏角測量を比較すると，1950年の噴火に際して生じた著しい伏角の減少はある程度回復したように思われる．又，1953年10月の小噴火に際しても，僅かではあるが，伏角の減少が確認された．

野増村に設けられた偏角変化計の記録から，15日平均を求め，柿岡地磁気観測所の値を基準として，その変化の模様を調べると，火山活動と偏角変化との間に有意な関係があるように見える．又島全体としての偏角変化の傾向を調べるために，1951年5月の観測結果と，1953年8月のそれとを比較すると，地下にあらたに帯磁が生じたような変化を示している．この量的な吟味は次報で行う予定である．