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21. *Geomagnetic and Geoelectric Studies of the Matsushiro Earthquake Swarm (1).*

By Tsuneji RIKITAKE, Yoshio YAMAZAKI, Yukio HAGIWARA, Kaoru KAWADA, Munehisa SAWADA, Yoichi SASAI, Teruhiko WATANABE, Kan-ichi MOMOSE, Toshio YOSHINO, Kazumi OTANI, Kazuko OZAWA and Yuko SANZAI,

Earthquake Research Institute.

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Summary

Observations of changes in the geomagnetic field by a proton precession magnetometer and a second-order G. S. I. magnetometer were carried out at stations in the Matsushiro earthquake area where we had an earthquake swarm in 1965. Two series of magnetic survey as well as an earth-current observation were also conducted there. A strong magnetic anomaly associated with a volcanic dome called Mt. Minakamiyama was found.

Comparisons between the results of magnetic observation there and those at the Kanozan Geodetic Observatory and the Oshima Magnetic Observatory seem to suggest occurrences of local anomalous changes in the geomagnetic field of the order of 10γ that might be associated with seismic activities although elimination of general magnetic changes such as magnetic storm, daily variation and the like was not quite complete. An anomalous change in earth-currents was also observed at the time of a relatively large earthquake.

1. Introduction

The earthquake swarm that occurred around the Matsushiro area, Nagano Prefecture in Central Japan from August, 1965 was certainly one of the biggest topics among the Japanese seismological community in recent years. A seismograph with a magnification of 100,000 at the Matsushiro Seismological Observatory, Japan Meteorological Agency began to record small shocks from August 3. The number of daily occurrences of shocks tended to increase day by day reaching more than 2,000 at the apparently most active period, *i.e.* Nov. 22-23, while the number of felt earthquakes also became large often exceeding 100 a day. A number of relatively large earthquakes having magnitudes 4-5 also took place during the 5-month period since the beginning of the activity. Details of the seismic activity are published by different authors elsewhere.

A team for geomagnetic and geoelectric study over the seismic area was sent to Matsushiro by the Earthquake Research Institute in the middle of October. A series of observations of the geomagnetic field and earth-currents have been conducted at observation stations situated immediately above the earthquake foci. Magnetic surveys were also conducted over the earthquake area. Although parts of these observations are still going on, the results observed by the middle of December will be reported in this paper.

2. Observation scheme

2-1. Proton precession magnetometer observation

At the beginning of the observation, a proton magnetometer which had been used as a ship-borne one was set at Station A(36.5°N, 138.2°E) in Fig. 1 on the top of Mt. Minakamiyama, which is a volcanic dome situated roughly at the centre of the earthquake area. Unfortunately, however, the magnetometer became out of order within a few days of operation. Accordingly, another proton magnetometer of mannual operation type was installed at Hirabayashi Village, Station B in Fig. 1, since around Nov. 20. Beat frequency between proton precession signal and a 2 kc standard frequency has been recorded by a pen-writing oscillograph several times or more a day.

2-2. Continual observation by a G. S. I. magnetometer

Absolute measurements by a second-order G. S. I. magnetometer have been performed at Station A on the top of Mt. Minakamiyama since around Oct. 20. Usually, measurements of declination and inclination were made several times a day. As only one member of the team has normally been at the station, it was difficult to measure the intensity of the geomagnetic field and so intensity measurement was performed only occasionally when two or more members were there. When a severe earthquake was felt, observations were conducted as many times as the observer could manage on the day, so that 30 or 40 observations were reported on some days.

2-3. Magnetic survey

Magnetic surveys over an area around Mt. Minakamiyama were conducted two times by use of a second-order G. S. I. magnetometer. Among the three geomagnetic elements, observation of the declination was omit-

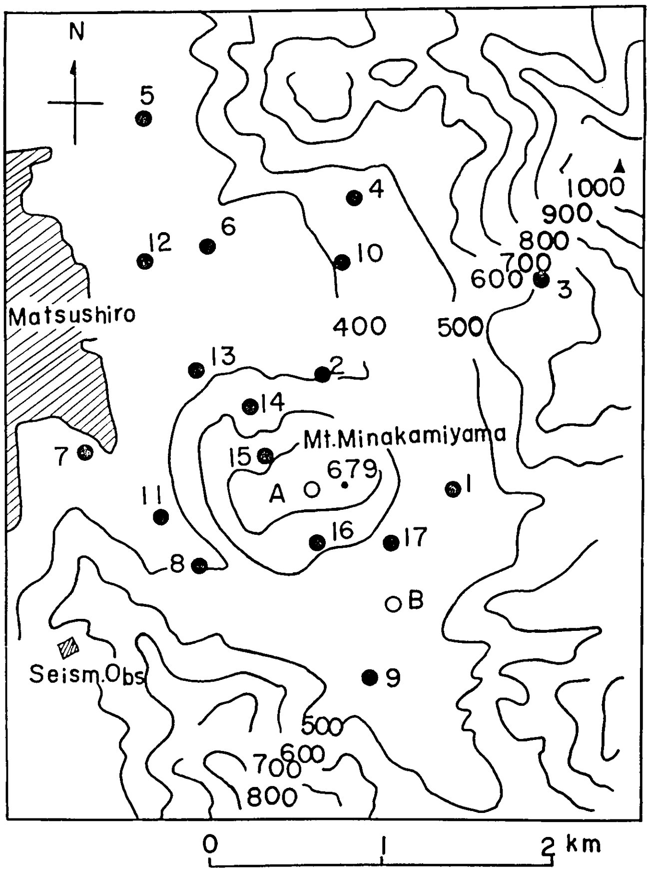

Fig. 1. Simplified map around the earthquake area. Topographic contours are shown in units of meter. Hollow circles A and B indicate the stations where continual observations are made, while solid circles show the stations occupied at the time of magnetic surveys.

ted in order to save time. In Fig. 1 are shown the 19 magnetic stations occupied by the team. The first survey was carried out during a period from Nov. 17 to 19, while the second from Dec. 20 to 22.

2-4. Earth-current observation

Potential differences between lead-tube electrodes buried in the ground at a depth of about 1 m were continuously recorded by pen-writing millivoltmeters with d. c. amplifiers at Station A. The electrode-distances were 64 m and 72 m respectively for the NS and EW components. The paper-speed was usually 60 mm/hour. It turned out that fluctuations of the earth's potential, probably due to stray electric currents from an electric railway running at a distance of a few kilometers from the observation station, were so large that diurnal variations were completely masked.

3. Local anomalous changes in the geomagnetic field and seismic activity

3-1. Declination and inclination at Station A

The values of declination and inclination observed at Station A are given in Table 1.

In the hope of eliminating general magnetic disturbances such as diurnal variation, magnetic storm and the like, the differences between the values of the inclination and declination at Station A as denoted by I_M and D_M and those at Kanozan Geodetic Observatory (35,3°N, 140.0°E), I_K and D_K, and at Oshima Magnetic Observatory (34.7°N, 139.4°E), I_O and D_O, are made.

It is doubtful, however, whether or not local anomalous changes in the geomagnetic field, if any, can be accurately detected by the above procedure because there is no guarantee that a general change is exactly the same at two stations widely distant from one another. According to previous experience[1),2)], differences in transient geomagnetic variations between two stations, 100 km apart say, may well exceed 10γ. As an example, the values of I_M-I_K and I_M-I_O for a period from Nov. 3 to 5 are shown in Fig. 2 in which we see large scatterings of the instantaneous values. Daily mean values with standard deviations are also plotted in the figure at 12 h every day. As the distances between Matsushiro and Kanozan and Matsushiro and Oshima exceed 200 km, to be bothered by such irregularities cannot be avoided. To make matters worse the Matsushiro-Kanozan-Oshima area is covered by the "Central Japan Anomaly" for short-period geomagnetic variations[3)].

Changes in the vertical component may well range from zero to a value equal to that in the horizontal one in the case of geomagnetic bays and similar changes in the anomalous area. It has also been reported that the differences in phase of the vertical component of S_q (solar daily variation) between observatories towards the west and the east of the area respectively is considerable.

1) T. YUKUTAKE, Y. HAGIWARA, Y. SASAI and T. WATANABE, *Spec. Bull. Earthq. Res. Inst.*, **8** (1964), 52.
2) N. FUJITA, *Journ. Geod. Soc. Japan*, **11** (1965), 8.
3) T. RIKITAKE, *Geophys. Journ. Roy. Astr. Soc.*, **2** (1959), 276.

Table 1. Declination (D_M) and Inclination (I_M) as observed on the top of Mt. Minakamiyama.

Date	Time	D_M	I_M
1965	h m		
Oct. 24	10 27	8°31.3'W	54°18.6'
	47	31.6	20.2
	13 04	32.1	19.0
	14 32	31.4	19.4
	15 09	30.0	19.0
	16 10	30.5	19.4
Oct. 25	16 28	31.5	19.8
	45	31.5	19.9
	17 22	30.7	20.1
	20 58	31.1	19.7
	21 23	30.9	20.0
Oct. 26	8 55	29.1	18.9
	9 16	30.8	18.8
	10 08	31.7	19.4
	41	30.2	19.2
	13 05	31.9	17.9
	19	32.4	17.8
	45	32.4	18.0
	16 25	29.8	17.9
	45	29.8	18.4
	17 09	29.6	18.3
	20 56	30.0	18.6
	21 21	30.0	18.5
Oct. 27	9 27	28.4	18.0
	36	28.4	18.1
	10 25	28.6	17.9
	38	28.5	18.0
	11 29	30.5	17.7
	45	30.7	18.1
	12 37	32.8	17.3
	54	33.3	17.3
	14 43	32.0	17.6
	53	32.0	18.4
	15 36	31.0	18.5
1965	h m		
Oct. 27	16 24	8°29.4'W	54°17.7'
	17 25	29.5	17.8'
	37	29.6	18.0
	19 00	30.5	18.1
	09	31.0	17.6
	25	30.6	18.1
Oct. 28	9 30	30.4	18.7
	47	29.3	18.7
	55	29.2	19.1
	10 03	29.9	19.1
	11	29.0	18.5
	12 17	32.6	18.0
	26	32.8	18.0
	32	33.5	18.0
	39	32.5	17.9
	47	31.9	17.9
	15 05	30.3	17.9
	15	30.2	18.4
	24	30.8	17.8
	34	30.8	18.6
	44	29.8	17.8
	18 52	30.8	18.1
	19 00	30.1	18.2
	11	30.5	18.6
	25	30.3	19.5
	41	31.2	19.5
	20 10	29.9	19.9
	27	30.0	20.1
Oct. 29	—	—	—
	16 43	29.7	19.7
	17 37	29.9	19.3
	43	30.1	19.2
	53	29.8	18.7
	20 11	30.4	19.1

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Date	Time	D_M	I_M
1965	h m		
Oct. 29	20	8°29.9'W	54°19.3'
	34	30.2	19.4
	48	30.3	19.4
	58	30.4	19.6
Oct. 30	10 32	28.4	18.1
	39	29.1	18.0
	48	28.8	18.2
	11 09	29.0	18.9
	17	30.1	18.5
	43	30.2	18.9
	56	30.9	18.6
	12 13	31.2	18.6
	25	32.0	18.5
	33	31.8	18.6
	41	32.2	18.9
	51	30.8	18.6
	16 08	30.2	19.3
	15	29.7	19.1
	25	29.7	19.5
	34	29.6	19.4
	19 15	28.8	19.4
	26	29.2	19.6
	41	29.4	19.9
	51	29.1	19.8
	21 09	29.0	20.0
	19	28.9	19.9
	32	29.0	20.1
	43	28.9	19.8
Oct. 31	9 28	26.0	19.5
	36	26.7	18.9
	15 53	31.7	18.5
	16 17	30.6	20.2
	48	31.0	18.6
	19 16	31.0	18.6
	25	31.1	18.2
	32	31.4	19.1
Nov. 1	10 20	28.6	19.1
	44	28.8	18.6

Date	Time	D_M	I_M
1965	h m		
Nov. 1	53	8°29.5'W	54°18.2'
	11 05	30.2	18.6
	13 07	31.8	18.5
	16	31.5	18.9
	30	32.2	18.3
	43	31.8	19.0
	15 48	29.5	18.5
	58	29.5	18.4
	16 08	29.3	18.0
	13	28.9	18.1
	18 34	29.8	18.3
	40	29.6	18.2
	20 02	29.9	18.3
	08	29.9	18.6
Nov. 2	9 55	28.8	19.1
	10 03	29.0	19.1
	10	29.9	19.1
	11 46	31.2	18.8
	54	31.2	19.0
	12 05	30.7	18.8
	13 08	31.9	17.8
	14	31.4	17.8
	15 11	30.1	18.5
	31	30.1	18.3
	38	29.0	18.9
	16 32	29.1	18.5
	37	29.5	18.5
	19 24	30.2	18.4
	31	30.1	18.1
	20 58	30.0	18.8
	21 04	30.3	18.7
Nov. 3	10 07	28.3	18.2
	13	28.5	18.0
	11 10	29.6	18.3
	22	29.8	18.2
	34	30.4	17.8
	40	30.7	17.5
	13 18	30.6	18.0

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Date	Time	D_M	I_M
1965	h m		
Nov. 3	29	8°31.5'W	54°18.4'
	38	30.3	18.0
	43	31.2	17.9
	17 57	29.6	18.6
	18 07	30.2	18.5
	19 14	29.8	18.4
	22	29.7	18.7
Nov. 4	10 10	28.1	17.4
	15	28.3	17.2
	11 16	28.7	16.9
	31	29.0	16.8
	40	30.3	16.3
	45	29.9	16.2
	13 25	30.3	16.1
	45	30.2	16.0
	55	30.4	16.0
	15 17	29.1	17.0
	28	28.8	16.9
	17 23	29.2	16.3
	29	29.4	16.7
	19 21	28.8	16.2
	28	28.7	16.8
Nov. 5	9 47	28.6	17.8
	55	29.0	17.9
	10 12	28.9	17.8
	27	30.4	16.7
	35	29.6	17.3
	43	29.1	17.2
	55	29.4	16.6
	11 05	29.8	16.1
	08	29.8	16.3
	13 26	30.3	16.1
	32	30.7	17.0
	39	30.4	16.6
	16 18	29.9	17.9
	26	30.6	17.9
	32	30.1	18.1
	19 02	29.5	18.1

Date	Time	D_M	I_M
1965	h m		
Nov. 5	08	8°29.7'W	54°17.9'
	21 00	30.0	17.8
	08	29.3	17.8
Nov. 6	9 18	32.1	19.3
	30	33.6	19.4
	38	33.3	19.1
	47	33.7	19.3
	10 38	32.9	19.4
	44	32.9	19.7
	52	33.5	19.4
	59	33.6	18.9
	11 32	34.0	20.2
	42	34.3	20.8
	48	34.2	20.1
	12 26	34.2	19.9
	31	35.3	19.7
	36	34.9	19.9
	13 17	34.4	20.0
	23	34.5	19.9
	14 31	31.9	20.0
	37	31.8	19.8
	16 55	30.4	19.7
	17 02	29.3	19.9
	19 00	30.3	20.0
	06	29.8	20.2
	17	29.1	20.1
	32	27.9	20.2
	36	28.1	20.6
	42	27.7	20.1
	49	27.8	20.3
	56	27.1	19.9
	20 01	27.7	20.1
	21 03	29.7	19.5
	10	29.2	19.7
	17	29.3	19.3
	27	29.3	19.5
	34	30.1	19.7
	21 40	29.6	19.4

(to be continued)

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Date	Time	D_M	I_M
1965	h m		
Nov. 6	45	8°29.8'W	54°19.5'
	52	30.3	19.4
Nov. 7	10 15	32.0	19.5
	25	32.5	19.4
	31	32.1	19.7
	11 38	32.1	19.2
	44	31.6	19.6
	49	32.4	19.5
	13 29	31.9	19.5
	34	31.9	19.0
	40	32.3	19.1
	15 03	30.9	19.3
	09	30.7	19.2
	17 09	30.2	19.8
	14	29.9	20.0
	19	30.3	20.0
Nov. 11	10 42	31.5	17.7
	11 06	30.7	17.5
	58	32.7	17.3
	12 54	32.5	17.5
	16 49	31.5	16.9
	17 06	31.2	17.4
	25	31.1	17.6
	49	31.8	17.5
	19 49	31.7	18.0
	20 14	31.7	17.8
	28	31.9	17.8
	44	31.6	18.2
Nov. 12	9 53	—	18.2
	12 34	—	18.1
	47	—	17.1
	13 00	—	17.8
	19 00	—	18.0
	19 15	—	17.6
	39	—	17.6
	20 04	—	17.6
	20	—	17.8

Date	Time	D_M	I_M
1965	h m		
Nov. 13	11 34	8°31.1'W	54°17.4'
	50	31.3	17.9
	12 08	32.0	17.4
	58	32.6	17.6
	16 53	30.0	18.3
	18 58	32.6	16.8
	19 37	30.6	19.0
	20 08	30.7	18.3
	33	30.2	18.7
	53	30.5	18.9
	21 19	30.3	18.6
	37	29.7	19.2
Nov. 14	20 46	—	18.3
	21 10	—	18.0
	40	—	18.2
	22 06	—	18.0
Nov. 15	10 13	28.2	18.2
	31	28.9	18.9
	50	29.3	17.6
	11 04	29.1	18.5
	23	29.1	19.0
	44	30.2	17.7
	12 13	29.1	17.6
	16 51	29.9	17.2
	17 11	31.2	15.8
	35	30.1	18.2
	57	30.4	18.1
	18 35	31.5	18.4
	21 29	29.6	18.6
	51	30.4	18.1
Nov. 16	11 05	—	16.8
	18	—	16.5
Nov. 20	15 37	—	19.8
	19 33	—	20.7
	55	—	20.7
	20 09	—	20.7

(to be continued)

(continued)

Date	Time	D_M	I_M
1965	h m		
Nov. 21	10 40	8°32.2'W	54°18.8'
	57	31.9	18.7
	11 14	32.6	18.9
	28	32.6	18.8
	19 09	31.5	19.4
	25	30.5	20.3
	48	31.8	18.1
	20 07	30.8	20.7
	26	31.7	19.0
Nov. 22	11 23	32.0	18.2
	46	32.2	17.9
	12 03	33.2	18.0
	13 20	—	17.3
	17 34	31.9	18.1
	19 11	30.7	18.9
	30	32.2	18.4
	58	31.3	18.6
	20 13	30.4	18.3
	28	31.1	18.4
	21 48	—	18.6
	22 05	—	18.0
	19	—	18.2
	43	—	18.2
Nov. 23	10 28	30.8	17.7
	11 03	30.9	17.6
	15	30.3	16.8
	27	31.0	17.7
	51	—	17.3
	12 57	32.3	17.6
	16 56	30.2	18.1
	17 15	30.3	18.2
	20 11	30.0	18.2
	21 32	31.0	17.8
	38	30.4	18.0
	44	30.7	18.1
Nov. 24	10 09	30.6	17.2
	13	31.1	16.9

Date	Time	D_M	I_M
1965	h m		
Nov. 24	18	8°30.8'W	54°17.6'
	20 24	30.4	17.0
	27	31.0	17.6
	41	31.7	17.8
	51	31.2	17.8
Nov. 26	10 06	30.6	17.5
	17	29.9	18.0
	31	29.4	16.7
	12 03	31.1	16.4
	11	31.5	16.4
	21	31.7	16.8
	57	—	17.1
	16 57	29.9	—
	17 09	29.8	17.6
	19 19	31.6	17.9
	34	29.7	17.6
	41	30.1	17.5
Nov. 27	10 05	30.0	18.1
	13	29.6	17.6
	25	29.9	18.2
	11 49	32.0	17.0
	12 00	32.2	17.1
	14	32.7	17.0
	16 47	30.1	17.5
	55	30.5	17.7
	17 07	30.1	17.1
	19 45	30.1	17.3
	52	30.4	18.1
	20 04	30.3	17.7
Nov. 28	10 01	29.1	16.8
	26	28.7	17.7
	47	29.0	17.5
	11 18	30.4	17.6
	25	30.2	18.1
	37	29.9	17.3
	16 53	29.7	17.2
	17 05	30.5	17.2

(to be contiuned)

(continued)

Date	Time	D_M	I_M
1965 Nov. 28	h m 15	8°29.8'W	54°17.3'
	19 22	30.7	17.2
	32	30.8	17.3
	45	—	17.4
Nov. 29	9 10	28.0	17.2
	17	28.2	17.2
	30	28.5	16.9
	11 17	29.7	16.5
	26	30.0	17.1
	36	30.3	16.7
	16 25	29.2	17.8
	34	29.4	17.7
	46	29.0	17.4
	19 25	30.5	17.7
	19 33	29.3	17.4
	47	30.0	17.9
Nov. 30	11 11	31.3	17.5
	39	31.9	18.4
	49	31.7	17.8
	15 43	30.2	17.0
	51	30.2	17.8
	16 03	29.2	16.9
Dec. 2	16 36	30.4	19.0
	44	31.2	19.4
	55	30.9	18.3
	19 49	30.2	19.7
	56	29.4	19.3
	20 03	29.5	18.7
	08	30.2	—
Dec. 3	11 00	31.0	18.2
	08	31.1	18.0
	18	31.3	18.5
	27	31.3	18.7
	35	31.4	18.1
	48	30.9	17.8
	16 26	29.8	18.6

Date	Time	D_M	I_M
1965 Dec. 3	h m 33	8°29.9'W	54°18.3'
	19 16	29.8	18.4
	23	29.7	18.3
	32	30.1	18.5
Dec. 4	11 40	31.6	18.0
	48	31.6	18.0
	58	31.4	18.0
	12 03	31.7	18.0
Dec. 5	11 09	32.5	18.1
	16	32.5	18.3
	21	32.4	18.1
	30	31.6	18.1
	16 21	31.1	17.8
	30	30.7	18.5
	38	30.8	18.2
	19 18	31.2	18.3
	27	31.0	18.0
	34	31.7	18.2
Dec. 7	10 48	31.8	17.4
	11 03	31.6	17.0
	11	31.4	17.2
	16 34	31.1	17.9
	42	31.0	18.0
	49	31.3	18.1
	18 57	30.9	18.1
	19 06	30.8	18.0
	13	31.0	18.1
Dec. 8	11 25	31.2	17.5
	33	31.6	17.8
	41	31.6	17.7
	17 02	30.8	17.3
	08	30.7	17.6
	16	30.8	17.8
	19 37	30.5	17.8
	44	30.7	17.7
Dec. 9	15 35	30.0	16.5

(to be continued)

(continued)

Date	Time	D_M	I_M	Date	Time	D_M	I_M
1965	h m			1965	h m		
Dec. 9	42	8°30.5'W	54°16.7'	Nov. 13	15 12	8°31.1'W	54°18.3'
	50	30.6	16.7		19	31.2	18.2
	20 58	31.3	17.1		26	31.0	18.5
Dec. 10	10 23	31.0	17.9		19 83	30.7	18.1
	31	31.1	17.4		43	30.9	18.2
	41	31.1	17.8		54	31.2	18.3
	19 33	31.1	18.0	Dec. 14	11 21	31.2	17.8
	41	30.9	18.0		26	31.1	18.0
Dec. 11	11 27	30.9	17.7		33	30.8	17.9
	36	31.5	17.8		16 25	29.5	17.7
	44	31.1	17.3		33	29.2	18.0
	18 38	31.1	18.2		40	29.3	18.1
	46	30.9	18.4	Dec. 15	10 46	31.1	18.1
Dec. 12	11 13	—	18.5		53	31.6	18.4
	21	—	18.0		11 01	31.0	18.2
	28	—	18.2		15 40	30.5	17.5
Dec. 13	11 08	31.5	18.4		46	30.8	17.7
	15	31.1	18.3		53	30.3	17.3
	22	31.3	18.3		19 21	31.0	17.8
					26	30.7	18.0

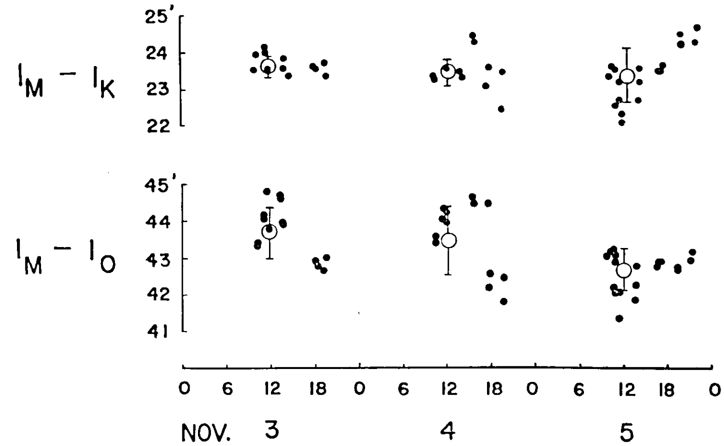

Fig. 2. An example of scatterings of the $I_M - I_K$ and $I_M - I_O$ values as observed from Nov. 3 to 5. The mean values of the respective days are indicated by big circles at noon on that day together with their standard deviations.

Since no other adequate way for eliminating non-local changes is known, however, we have to rely on daily mean values in discussing a local anomalous change in the Matsushiro area. Fujita[2] reported that the accuracy of mean values after a reduction procedure would be less than $\pm 5\gamma$ for a first-order magnetic survey for which observations during one day with an hour interval are used. It was also concluded by him that, in the case of a second-order survey for which only a few observations are used, the accuracy would be less than $\pm 10\gamma$. Fujita's argument may also be applied to the present series of observations, so that the accuracy of daily mean value in the present case would generally be smaller than ± 1 minute of arc.

In Table 2 are given the daily mean values of D_M, I_M, D_K, I_K, D_O, I_O, $D_M - D_K$, $I_M - I_K$, $D_M - D_O$ and $I_M - I_O$. These are graphically shown in Figs. 3a and 3b in which the occurrences of large earthquakes (magnitude 4 or larger) are also indicated.

At a glance, the parallelism between daily mean curves, both for the declination and inclination, at Matsushiro, Kanozan and Oshima is apparent although we sometimes find points which widely deviate from the general tendencies. For instance, D_K and D_O on Oct. 30 seem to jump up one minute or more from the general trends, while no such jumping can be seen in D_M. In such a case, it would be natural to suppose that the declination over the Kanozan-Oshima area behaved anomalously though nothing is known about the cause, so that the depressions on that day as seen in the difference curves would have nothing to do with the Matsushiro activity.

We sometimes observe significant differences even in the geomagnetic elements between Kanozan and Oshima, the distance between the two observatories amounting to only 80 km. Examples of the instantaneous value of such differences have already been shown in Fig. 2. Daily mean values are sometimes likely to suffer to some extent from such a local effect. It is unreasonable, therefore, to expect exactly the same curves for $D_M - D_K$ and $D_M - D_O$ and $I_M - I_K$ and $I_M - I_O$ even if we take daily mean values. At this point, it would perhaps be fair to say that the base-line value, especially for the inclination, might be subjected to a slight drift at Oshima Magnetic Observatory because of temperature effect.

In spite of the above defects, the curves in Figs. 3a and 3b might reflect a local anomalous change in the geomagnetic field at Station A. One of the most marked results would certainly be the westerly shift

Table 2. Daily mean values of the declination (D) and inclination (I) at Station A, Kanozan and Oshima as respectively denoted by M, K and O. The differences in each element between Station A and Kanozan and Station A and Oshima are also indicated.

Date	D_M	I_M	D_K	I_K	D_O	I_O	D_M-D_K	D_M-D_O	I_M-I_K	I_M-I_O
1965										
Oct. 24	8°31.1′W	54°19.3′	6°05.5′W	47°55.6′	4°14.4′W	48°35.8′	2°25.6′	4°16.7′	6°23.7′	5°43.5′
25	31.1	19.9	05.2	55.5	14.4	36.5	25.9	16.7	24.4	43.4
26	30.6	18.5	04.9	54.8	13.9	35.1	25.7	16.7	23.7	43.4
27	30.4	17.9	04.4	54.4	13.4	34.6	26.0	17.0	23.5	43.3
28	30.7	18.6	05.0	55.0	13.7	35.0	25.7	17.0	23.6	43.6
29	30.1	19.3	04.8	54.9	13.5	35.7	25.3	16.6	24.4	43.6
30	29.8	19.1	05.5	54.9	14.4	35.2	24.3	15.4	24.2	43.9
31	29.9	19.0	04.1	54.8	13.1	35.4	25.8	16.8	24.2	43.6
Nov. 1	30.1	18.5	04.9	54.8	13.4	35.0	25.2	16.7	23.7	43.5
2	30.1	18.6	05.0	54.9	13.7	35.0	25.1	16.4	23.7	43.6
3	30.0	18.2	04.7	54.8	13.3	34.6	25.3	16.7	23.4	43.6
4	29.0	16.7	04.5	53.2	12.7	33.6	24.5	16.3	23.5	43.1
5	29.8	17.3	04.7	54.0	13.0	34.6	25.1	16.8	23.3	42.7
6	31.3	19.8	06.2	56.2	14.6	36.7	25.1	16.7	23.6	43.1
7	31.4	19.5	06.3	55.9	15.2	36.4	25.1	16.2	23.6	43.1
8	—	—	—	—	—	—	—	—	—	—
9	—	—	—	—	—	—	—	—	—	—
10	—	—	—	—	—	—	—	—	—	—
11	31.3	17.6	04.9	54.4	13.5	34.4	25.7	17.6	23.2	43.2
12	—	17.8	—	54.3	—	34.6	—	—	23.5	43.2
13	30.3	18.2	04.8	54.9	13.9	34.6	25.5	16.4	23.3	43.6
14	—	18.1	—	54.7	—	35.0	—	—	23.4	43.1
15	31.0	18.0	04.7	54.4	13.9	34.4	26.3	17.1	23.6	43.6
16	—	16.7	—	53.5	—	33.7	—	—	23.2	43.0
17	—	—	—	—	—	—	—	—	—	—
18	—	—	—	—	—	—	—	—	—	—
19	—	—	—	—	—	—	—	—	—	—
20	—	20.4	—	56.8	—	36.5	—	—	23.6	43.9

(to be continued)

Table 2. (continued)

Date	D_M	I_M	D_K	I_K	D_O	I_O	D_M-D_K	D_M-D_O	I_M-I_K	I_M-I_O
21	8°31.7′W	54°19.2′	6°05.7′W	47°55.3′	4°14.0′W	48°35.3′	2°26.0′	4°17.7′	6°23.9′	5°43.9′
22	31.7	18.2	05.3	54.4	13.9	34.7	26.4	17.8	23.8	43.5
23	30.7	17.8	04.6	54.2	13.4	34.1	26.1	17.3	23.6	43.7
24	31.1	17.5	04.8	54.0	13.8	33.6	26.3	17.3	23.5	43.9
25	—	—	—	—	—	—	—	—	—	—
26	30.5	17.2	04.7	53.8	13.6	33.9	25.8	16.9	23.4	43.3
27	30.7	17.5	04.7	54.1	13.6	34.0	26.0	17.1	23.4	43.5
28	29.9	17.4	04.1	53.8	13.1	34.0	25.8	16.8	23.6	43.4
29	29.3	17.3	03.5	53.4	12.4	33.6	25.8	16.9	23.9	43.7
30	30.8	17.6	04.7	53.9	13.4	34.3	26.1	17.4	23.7	43.3
Dec. 1	—	—			—	—		—		—
2	—	19.1	—	54.7	—	35.3	—	—	24.4	43.8
3	30.6	18.3	04.6	55.0	13.3	34.8	26.0	17.3	23.3	43.5
4	31.6	18.0	05.0	54.3	13.6	34.5	26.6	18.0	23.7	43.5
5	31.6	18.2	05.0	54.6	13.5	35.3	26.6	18.1	23.6	42.4
6	—	—	—	—	—	—	—	—	—	—
7	31.2	18.2	05.8	54.4	13.2	33.7	25.4	18.0	23.8	44.5
8	31.0	17.7	04.0	54.1	13.3	33.9	27.0	17.7	23.6	42.8
9	30.6	16.5	03.7	53.4	12.7	33.7	26.9	17.9	23.1	42.8
10	31.0	17.8	04.3	54.2	13.3	34.0	26.7	17.7	23.6	43.8
11	31.1	17.5	04.1	53.8	13.4	34.0	27.0	17.7	23.7	43.5
12	—	18.2	—	54.8	—	34.5	—	—	23.4	43.7
13	31.1	18.3	04.7	54.9	13.8	34.9	26.4	17.3	23.4	43.4
14	30.2	17.9	04.4	54.3	13.4	34.9	25.8	16.8	23.6	43.0
15	30.9	17.9	04.4	54.4	13.3	34.6	26.5	17.6	23.5	43.3
16	—	—	—	—	—	—	—	—	—	—
17	30.2	16.9	03.1	53.8	12.5	33.4	27.1	17.7	23.1	43.5
18	30.1	17.0	03.0	54.3	12.6	34.7	27.1	17.5	22.7	42.3
19	32.0	18.7	04.7	56.3	13.9	35.7	27.3	18.1	22.4	43.0

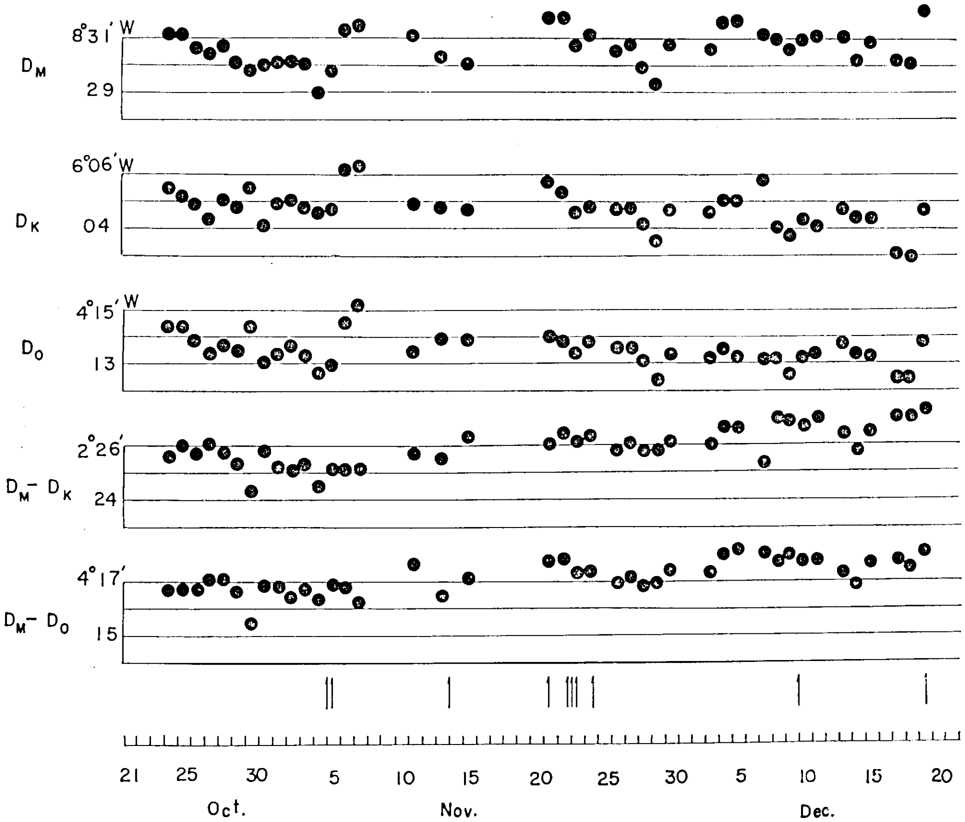

Fig. 3a. Changes in D_M, D_K, D_O, $D_M - D_K$ and $D_M - D_O$. Occurrences of large earthquakes are indicated with arrows.

of the declination which is likely to have taken place around the middle of the observation period. The shift is estimated as being about 1.5′. Nothing is known about the cause of such a shift. Although the possibility that the shift might be caused by a sort of seasonal change cannot be ruled out, it is suggestive that the shift took place at a period during which the seismic activity was extremely high as can be seen in Fig. 3a. Superposing on such a long-term change, fluctuations of difference curves for the declination of the order of 1 minute of arc may be observable. It might be pointed out that large earthquakes are associated with westerly deviations although such a tendency is clearly seen only for the latter half of the observation period. It is dangerous, however, to say anything definite because the difference curves are contaminated by unwanted changes as mentioned in the preceding para-

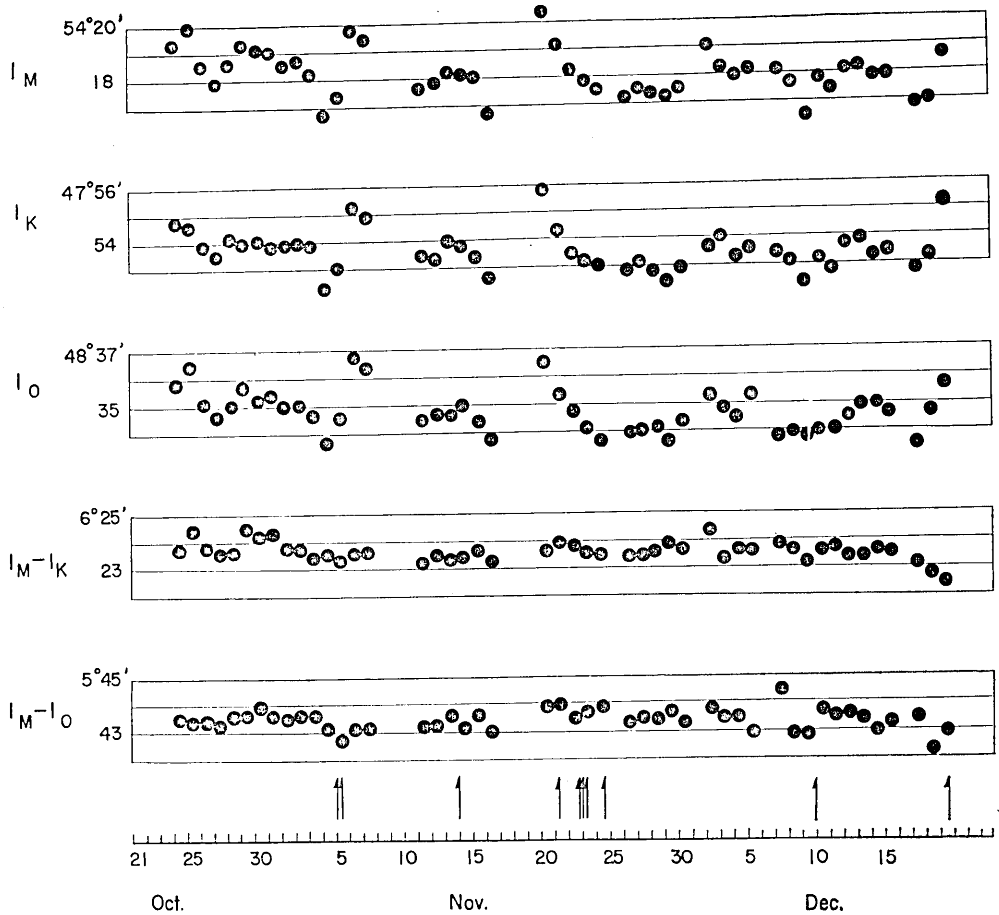

Fig. 3b. Changes in I_M, I_K, I_O, $I_M - I_K$ and $I_M - I_O$. Occurrences of large earthquakes are indicated with arrows.

graphs and also only a few anomalous changes are experienced.

Turning to the difference curves of the inclination as shown in Fig. 3b, we also observe fluctuations of the order slightly less than 1 minute of arc. Taking into consideration the fact that the horizontal and total intensities respectively amount to 0.3 and 0.5 Gauss at Station A, the order of fluctuation of the EW component is approximately the same as that of the vertical component. A long-term change in the inclination during a period from the end of October to that of November might be related to the seismic activity although its amplitude would be only 1 minute of arc or thereabouts. Apparent correlation between the fluc-

Table 3. Total intensity values (F_M) observed at Station B.

Date	Time	F_M
1965	h m	
Nov. 19	17 54	46913.3 γ
	18 00	14.4
Nov. 20	15 19	19.7
	21	16.9
	23	18.0
Nov. 21	14 46	16.6
	48	19.0
	50	13.3
	52	15.2
	59	16.6
	15 01	17.2
	03	15.0
	05	17.6
Nov. 22	15 38	24.8
	40	26.7
	42	27.2
	44	26.7
Nov. 23	14 55	34.0
	57	34.0
	15 23	30.3
	26	32.8
	28	32.6
	30	32.6
	31	34.0
	32	29.1
Nov. 24	15 54	39.9
	56	35.6
	57	37.3
	16 03	38.0
	06	35.6
Nov. 25	11 29	21.1
	31	21.1
	12 11	31.6
	12	29.3
1965	h m	
Nov. 25	14	46924.0 γ
	17 44	32.6
	46	22.7
	47	26.9
	58	26.2
	18 00	27.4
	02	30.9
	03	33.3
Nov. 26	10 02	28.1
	05	27.2
	06	28.1
	40	30.9
	41	30.9
	42	28.1
	44	27.0
	46	27.2
	58	30.9
	11 18	25.8
	19	24.6
	21	24.1
	23	24.4
	12 15	21.8
	17	21.1
	19	18.5
	13 40	29.3
	41	31.9
	42	29.3
	45	33.5
	14 34	29.8
	15 04	31.4
	25	30.5
	49	34.7
	51	35.6
	16 35	31.4
	36	31.2
	17 20	28.8
1965	h m	
Nov. 26	22	46925.8 γ
	17 24	28.4
	26	26.0
Nov. 27	10 12	14.7
	13	17.3
	19	18.5
	21	16.9
	25	15.2
	26	16.4
	27	11.5
	30	13.1
	52	13.1
	13 30	30.7
	32	30.7
	34	30.2
	14 47	34.5
	49	32.8
	50	34.5
Nov. 28	12 26	26.7
	37	30.7
	39	30.0
	40	27.9
	15 51	38.0
	53	35.6
	54	33.0
Nov. 29	12 39	24.8
	41	24.8
	43	19.7
	13 03	20.1
	06	20.1
	14 59	38.9
	15 03	42.2
	05	38.2
Nov. 30	13 20	30.0
	22	26.5

(to be continued)

(continued)

Date	Time	F_M
1965	h m	
Nov. 30	14 34	46929.3 γ
	36	43.9
	37	44.8
Dec. 1	—	—
Dec. 2	—	—
Dec. 3	12 01	25.3
	04	22.0
	05	23.2
	07	24.8
	09	26.5
	10	22.7
	13 53	26.0
	54	17.5
	56	17.8
	58	17.8
	15 15	21.8
	17	22.5
	19	21.1
	20	22.2
	30	20.1
	40	18.5
	51	17.5
	53	18.0
	55	18.7
	16 22	25.8
	24	25.3
	26	23.4
	28	26.0
	29	26.0
Dec. 4	13 19	30.9
	21	29.1
	23	34.9
	24	31.8
	26	31.8
Dec. 5	13 17	29.8
	18	30.0

Date	Time	F_M
1965	h m	
Dec. 5	20	46929.3 γ
	22	30.0
	13 24	28.8
	25	30.2
	27	30.2
Dec. 6	13 20	29.3
	21	28.8
	25	28.8
	26	28.1
	28	27.2
	30	29.1
Dec. 7	13 15	32.0
	17	30.7
	18	35.2
	20	31.8
	22	33.3
	24	32.3
	28	31.4
	15 29	29.3
	30	30.7
Dec. 8	13 23	24.1
	25	26.0
	26	25.5
	28	26.5
	29	26.7
	31	26.0
Dec. 9	11 52	34.5
	54	31.9
	55	32.8
	59	34.0
	12 00	34.2
	02	31.9
Dec. 10	11 34	29.8
	36	32.6
	37	28.8
	39	30.7

Date	Time	F_M
1965	h m	
Dec. 10	42	46935.4 γ
Dec. 11	14 40	23.7
	42	23.7
	44	24.1
	45	25.8
	47	26.9
	48	24.8
Dec. 12	13 16	30.7
	18	33.3
	20	30.9
	22	31.6
	23	29.1
	25	30.0
	27	31.6
Dec. 13	12 08	19.4
	09	21.1
	11	20.4
	12	19.9
	14	19.7
	16	16.4
Dec. 14	12 04	28.8
	06	26.2
	07	33.0
	11	28.8
	12	25.3
	14	26.0
Dec. 15	12 06	24.8
	08	23.4
	09	23.2
	11	25.3
	13	23.9
Dec. 16	13 26	33.5
	25	30.7
	27	31.6
Dec. 17	12 12	26.9

(to be continued)

(continued)

Date	Time	F_M	Date	Time	F_M	Date	Time	F_M
1965	h m		1965	h m		1965	h m	
Dec. 17	14	46929.1 γ	Dec. 18	12 04	46927.2 γ	Dec. 19	12 19	46918.0 γ
	15	30.0		11	28.1		24	16.4
				16	23.7		26	18.0

Table 4. Daily mean values of total intensity observed at Station B (F_M), Kanozan (F_K), Oshima (F_O) and their differences.

Date	F_M	F_K	F_O	F_M-F_K	F_M-F_O
	γ	γ	γ	γ	γ
Nov. 19	46912.4	—	46480.2	—	432.2
20	18.2	45531	483.1	1387	435.1
21	16.3	28	482.0	88	434.3
22	26.4	40	496.5	86	429.9
23	32.4	47	497.4	85	435.0
24	37.3	53	505.3	84	432.0
25	27.2	41	490.9	86	436.3
26	28.3	44	496.9	84	431.4
27	23.1	37	491.5	86	431.6
28	31.7	45	499.6	87	432.1
29	28.4	44	498.1	84	430.3
30	33.7	56	506.3	78	427.4
Dec. 1	—	—	—	—	—
2	—	—	—	—	—
3	22.9	33	488.1	89	434.1
4	31.8	43	498.5	89	433.1
5	29.5	42	494.6	88	434.9
6	28.5	39	493.4	90	435.1
7	30.9	45	500.6	86	430.3
8	25.8	42	497.4	84	428.4
9	33.2	51	505.8	82	427.4
10	31.5	45	503.4	87	428.1
11	24.8	—	491.5	—	433.3
12	31.0	42	498.3	89	432.7
13	19.5	33	489.7	87	429.8
14	28.0	45	501.1	83	426.9
15	24.1	40	495.3	84	428.8
16	31.9	47	500.9	85	431.0
17	28.7	42	498.9	87	429.8
18	26.3	41	495.7	85	430.6
19	17.5	25	482.2	93	435.3

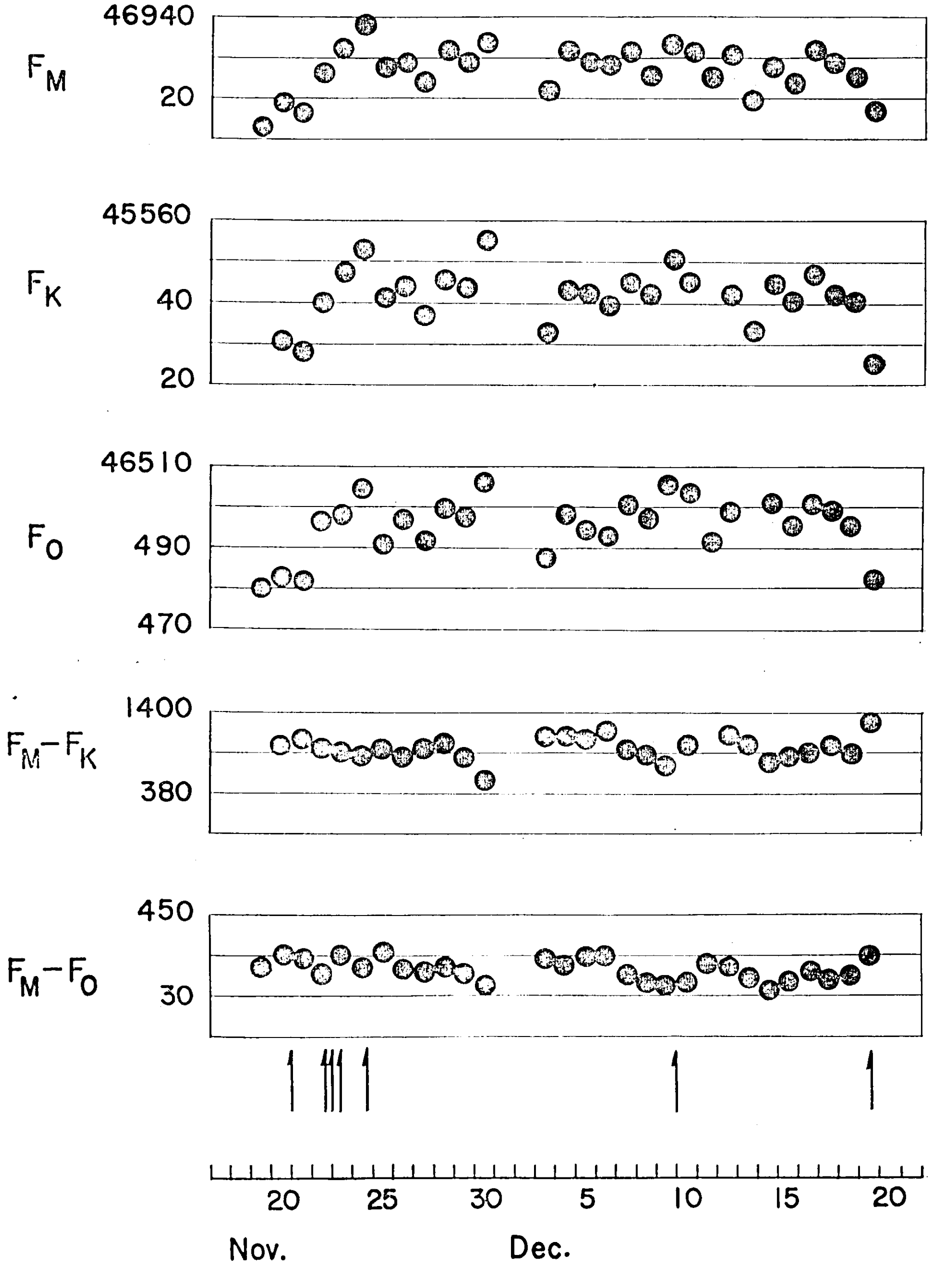

Fig. 4. Changes in F_M, F_K, F_O, F_M-F_K and F_M-F_O. Occurences of large earthquakes are indicated with arrows.

tuations of the inclination and the occurrences of large earthquakes is not as good as that for the declination. But a few sharp decreases in the inclination might be associated by occurrences of large earthquakes.

The present earthquakes occurring in a roughly circular area having a radius of several kilometers, it would not be reasonable to think that all these earthquakes affect equally the magnetic field at Station A, which is situated roughly at the centre of the earthquake area, even if we take for granted a seismo-magnetic effect. In view of this, it would be difficult to say something definite about the relationship between the difference curves and the degree of seismic activity until more sophisticated analyses are achieved.

3-2. Total intensity at Station B

The total intensity values as measured by a proton precession magnetometer at Station B during a period from Nov. 19 to Dec. 19 are given in Table 3. Meanwhile the total intensity values for the same instants also recorded by proton magnetometers at Kanozan and Oshima were read off from the records. Daily mean values of these three stations as denoted respectively by F_M, F_K and F_O are then calculated and given in Table 4 in which daily means of F_M-F_K and F_M-F_O are also shown.

F_M, F_K, F_O, F_M-F_K and F_M-F_O are then graphically shown in Fig. 4 together with the occurrences of relatively large earthquakes. Although the difference curves exhibit fluctuations of the order of 5γ or so, it is feared that the effect of general changes cannot be completely eliminated for the same reason as that mentioned in the last subsection. Since the observation period for the total intensity covers only a month, it would be premature to discuss the possible relationship between the local anomalous change and the seismic activity.

4. Results of the magnetic surveys

4-1. Magnetic anomalies as revealed by the survey

Two series of magnetic survey by a second-order G. S. I. magnetometer were carried out over an approximately $3\,\text{km}\times4\,\text{km}$ area around Mt. Minakamiyama during the periods from Nov. 17 to 19 and from Dec. 20 to 22. These surveys are here called Survey I and Survey II respectively. Total intensity and inclination were measured at 19 stations. The results of the surveys are tabulated in Tables 5a-5s. It is regrettable that the accuracy of the intensity measurements was not high, $\pm30\gamma$ or so, owing to some mishandling of the potentiometer system.

Table 5a. Station No. 1 Makiuchi.

Survey I				Survey II			
Date	Time	I	F	Date	Time	I	F
1965				1965			
Nov. 17	13h28.5m	50°07.3′		Dec. 21	10h51.5m	50°06.9′	
	51.5	07.9			11 02.5	06.7	
	14 00.0		46,580γ		03.5		46,500γ
	10.5	08.0			10.0	06.2	
	13.0		610		11.5		510
					17.0	06.2	
					18.0		510

Table 5b. Station No. 2 Han-nya-ji.

Survey I				Survey II			
Date	Time	I	F	Date	Time	I	F
1965				1965			
Nov. 17	15h03.5m	49°48.1′	—	Dec. 21	11h48.5m	49°46.0′	—
	13.5	48.3			12 00.0	46.6	
	15.5		46,450γ		02.0		46,650γ
					11.0	46.1	
					12.0		670
	35.0	48.2			20.0	46.7	
	36.0		440		21.5		650

Table 5c. Station No. 3 Takimoto.

Survey I				Survey II			
Date	Time	I	F	Date	Time	I	F
1965				1965			
Nov. 17	16h19.0m	49°21.1′	—	Dec. 21	13h04.0m	49°19.8′	
	29.0	21.0			10.5	19.9	
	38.5	20.8			12.0		46,531γ
	55.5	20.8			23.5	19.6	
	58.5		46,520γ		24.5		522
	17 07.0	20.6			30.5	19.9	
	09.0		520		31.5		523

Table 5d. Station No. 4 Iwasawa.

Survey I				Survey II			
Date	Time	*I*	*F*	Date	Time	*I*	*F*
1965				1965			
Nov. 17	18h00.5m	49°55.4′		Dec. 21	14h13.5m	49°55.0′	
	13.0	55.1			18.0	56.4	
	15.0		46,626γ		19.5		46,690γ
					27.0	55.9	
					28.0		700
	37.5	55.0			33.5	55.9	
	39.0		626		34.5		710

Table 5e. Station No. 5 Kagai.

Survey I				Survey II			
Date	Time	*I*	*F*	Date	Time	*I*	*F*
1965				1965			
Nov. 17	20h26.0m	49°58.0′		Dec. 21	19h48.5m	49°57.4′	
	37.0	57.8			58.0	58.0	
	42.0		46,760γ		20 01.5		46,730γ
	50.5	58.6			09.0	57.7	
	52.5		780		11.0		740
	21 02.0	58.4			31.0	58.2	
	04.5		770		33.5		750

Table 5f. Station No. 6 Nakagawa.

Survey I				Survey II			
Date	Time	*I*	*F*	Date	Time	*I*	*F*
1965				1965			
Nov. 18	9h01.0m	49°42.3′		Dec. 21	15h54.5m	49°43.5′	
	21.0	42.2			59.5	43.8	
	22.5		46,380γ		16 01.0		46,720γ
	29.5	42.2			07.0	43.6	
	31.0		400				
	39.0	42.3			15.0	43.6	
	41.0		400		16.0		720

Table 5g. Station No. 7 Kamiara-machi.

Survey I				Survey II			
Date	Time	*I*	*F*	Date	Time	*I*	*F*
1965				1965			
Nov. 18	10h28.5m	50°08.9′		Dec. 22	11h32.5m	50°07.3′	
	36.5	08.6			37.5	07.5	
	38.0		46,650γ				
	45.0	08.6			43.0	06.9	
	46.5		670		44.5		46,620γ
	54.0	08.9			57.0	07.2	
	55.5		650		58.0		622

Table 5h. Station No. 8 Miyazaki.

Survey I				Survey II			
Date	Time	*I*	*F*	Date	Time	*I*	*F*
1965				1965			
Nov. 18	11h27.0m	49°08.1′		Dec. 22	13h19.0m	49°07.1′	
	33.5	08.1			23.5	07.2	
	36.5		46,600γ				
	46.5	08.1			29.0	07.3	
	48.5		600		31.5		46,590γ
					40.5	06.9	
					42.5		580

Table 5i. Station No. 9 Kake.

Survey I				Survey II			
Date	Time	*I*	*F*	Date	Time	*I*	*F*
1965				1965			
Nov. 18	13h10.0m	40°49.7′		Dec. 21	9h28.0m	49°49.4′	
	17.5	49.4			36.0	49.5	
	18.5		47,000γ		57.5	49.2	
	24.5	49.5			59.5		47,000γ
	26.5		47,000		10 06.0	49.1	
	32.0	50.1			07.5		46,990
	33.5		47,000		13.0	49.5	
					14.0		46,970

Table 5j. Station No. 10 Sugema.

Survey I				Survey II			
Date	Time	*I*	*F*	Date	Time	*I*	*F*
1965							
Nov. 18	15h35.5m	49°49.7′		The peg has been lost.			
	37.0		46,610γ				
	44.5						
	46.5		610				
	52.0						
	53.5		610				

Table 5k. Station No. 11 Miyazaki Jinja.

Survey I				Survey II			
Date	Time	*I*	*F*	Date	Time	*I*	*F*
1965				1962			
Nov. 18	16h57.5m	50°03.0′	—	Dec. 22	12h16.0m	50°02.4′	—
	17 02.0	02.9	—		20.0	02.5	—
	05.0	02.9	—		24.0	02.2	—

Table 5l. Station No. 12 Tanaka.

Survey I				Survey II			
Date	Time	*I*	*F*	Date	Time	*I*	*F*
1965				1965			
Nov. 19	10h06.0m	49°55.0′		Dec. 21	16h40.0m	49°56.2′	
	09.0	55.4			45.0	56.0	
	11.0		46,740γ		52.0	56.0	
	17.0	55.4			17 09.5	56.0	
	18.5		750		31.5	56.3	
					34.5		46,690γ
					42.0	56.1	
					44.0		690
					50.5	56.5	
					52.5		700

Table 5m. Station No. 13 Dainichi Ike.

Survey I				Survey II			
Date	Time	*I*	*F*	Date	Time	*I*	*F*
1965				1965			
Nov. 19	11h04.0m	49°50.3′		Dec. 22	9h26.0m	49°49.2′	
	11.0	50.2			31.5	49.6	
	12.0				33.0		45,780γ
	22.0	50.2			39.0	49.4	
	24.0		45,740γ		41.0		800
	28.5	50.4			48.0	49.7	
	30.5		720		49.5		800

Table 5n. Station No. 14 Minakami-1.

Survey I				Survey II			
Date	Time	*I*	*F*	Date	Time	*I*	*F*
1965				1965			
Nov. 19	12h02.5m	50°10.4′		Dec. 22	10h23.0m	50°09.4′	
	08.0	10.4			28.0	09.9	
	10.0		47,230γ		29.5		47,230γ
	15.5	10.1			35.0	10.1	
	17.0		220		37.0		230
	22.5	10.4			43.5	09.9	
	23.5		230		45.5		230

Table 5o. Station No. 15 Minakami-2.

Survey I				Survey II			
Date	Time	*I*	*F*	Date	Time	*I*	*F*
1965				1965			
Nov. 19	12h57.0m	51°11.9′		Dec. 20	15h44.0m	51°12.5′	
	13 02.0	12.1			52.5	12.7	
	04.0		46,700γ		16 04.0	12.8	
	10.5	12.2			06.0		46,730γ
	13.0		690				
	22.0	11.7			24.0	12.5	
	23.0		690		25.5		710

Table 5p. Station No. 16 Minakami-3.

Survey I				Survey II			
Date	Time	*I*	*F*	Date	Time	*I*	*F*
1965				1965			
Nov. 19	14h59.0m	49°25.5′		Dec. 22	14h17.0m	49°24.0′	
	15 07.5	25.6			26.5	24.2	
	09.0		47,030γ		28.0		
	15.5	25.5			34.5	24.0	
	17.0		030		36.0		47,030γ
					44.5		020

Table 5q. Station No. 17 Minakami-4.

Survey I				Survey II			
Date	Time	*I*	*F*	Date	Time	*I*	*F*
1965				1965			
Nov. 19	15h54.0m	49°12.6′		Dec. 22	15h15.5m	40°11.9′	
	16 01.0	12.8			21.0	11.8	
	02.5		47,840γ		22.0		47,730γ
	07.5	12.8			28.0	11.6	
					29.0		730
	22.5	12.6			34.5	11.7	
	24.5		840		35.5		730

Table 5r. Station No. 18 Hirabayashi (Station B).

Survey I				Survey II			
Date	Time	*I*	*F*	Date	Time	*I*	*F*
1965				1965			
Nov. 19	17h04.0m	49°34.3′		Dec. 22	16h10.5m	49°32.2′	
	19.0	34.1			18.5	32.3	
	21.0		46,710γ				
	27.5	34.5			28.0	32.5	
	29.0		710		29.5		46,930γ
					43.0	32.4	
					44.0		920

Table 5s. Station No. 19 Top of Minakami (Station A).

Survey I				Survey II			
Date	Time	I	F	Date	Time	I	F
1965				1965			
Nov. 20	19h32.5m	54°20.7′	—	Dec. 20	14h38.0m	54°18.0′	
	54.5	20.7	—		45.0	18.1	
	20 08.5	20.7	—		46.5		
					51.0	17.8	
					52.5		49,460γ
					56.5	18.3	
					58.0		440

But individual observations of the inclination are certainly within an error of ±0.2′.

The normal values of the geomagnetic elements there are picked up from the magnetic charts published by the Geographical Survey Institute, *i.e.* the following values are adopted:

Inclination: $I_0=50°00'$,
Total intensity: $F_0=46980\gamma$,
Horizontal intensity: $H_0=30200\gamma$,
Vertical intensity: $Z_0=35990\gamma$.

The anomaly for each element is defined as the difference between the observed values and the normal one. In Figs. 5a, 5b, 5c and 5d are respectively shown the anomaly charts for the inclination (I), total intensity (F), horizontal intensity (H) and vertical intensity (Z). It is noticeably seen in all the anomaly charts that Mt. Minakamiyama is strongly magnetized roughly in the direction of the present geomagnetic field. Although the height of its top is only 250 m or so from the surrounding plane area, the inclination increases by an amount exceeding 4 degrees on the summit of the mountain.

If we assume that the mountain body is uniformly magnetized, the mean intensity of magnetization is estimated as 3.9×10^{-3} e.m.u./cm^3 by making use of a method similar to the one developed by Rikitake[4]. The mean density of the mountain body can also be estimated approximately as 2.2 g/cm^3 from the results of a gravity survey[5]. The intensity of natural remanent magnetization of rocks composing the mountain is

4) T. RIKITAKE, *Bull. Earthq. Res. Inst.*, **30** (1952) 71.
5) I. MURATA and H. TAJIMA, Personal communication.

then estimated as 1.8×10^{-3} e.m.u./gr.

Laboratory experiments on rock specimens sampled from Mt. Minakamiyama were also made. The results are summarized in Table 6. It is confirmed that the mean intensity as determined from the analysis of the magnetic survey falls in the range of intensity values actually measured for the rock samples.

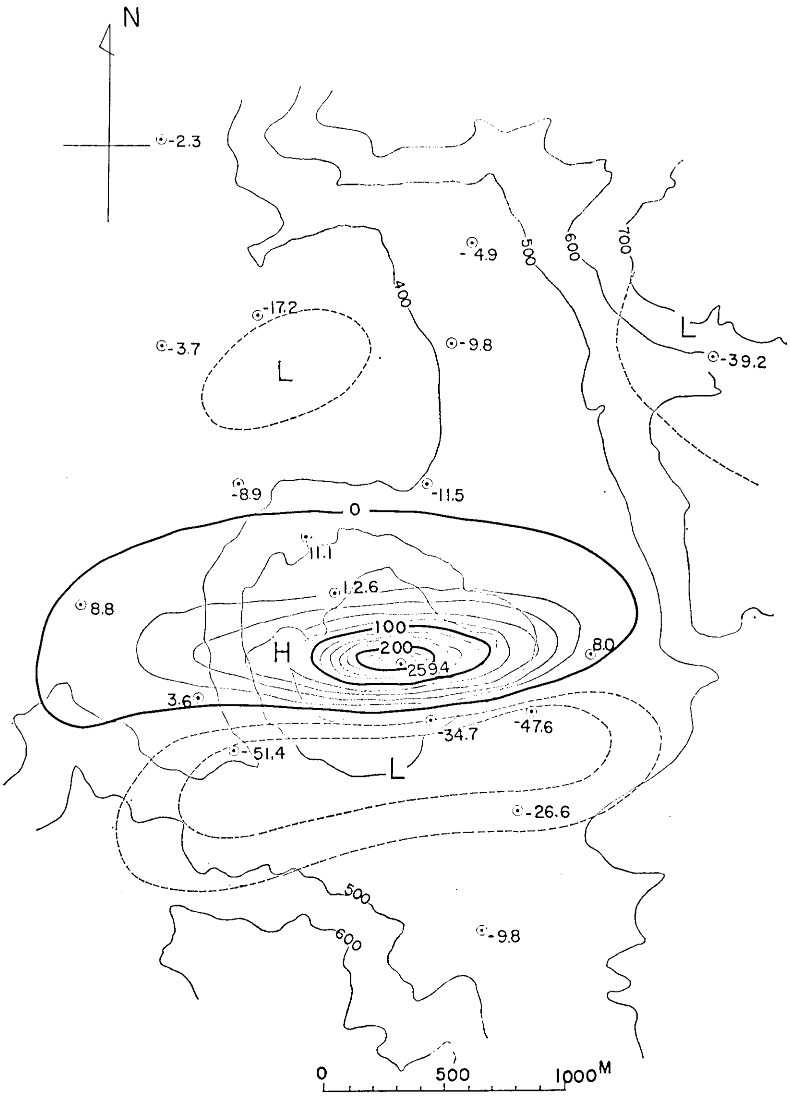

Fig. 5a. Anomaly of the inclination in units of minute of arc.

If one carefully examines the anomaly patterns, one would notice a marked fact that, in the total intensity map for example, the area in which positive anomaly is observed extends to the north well beyond the summit of the mountain. Such a distribution suggests either that the magnetization towards the north of the mountain is stronger than that towards the south or that another magnetized body might be buried

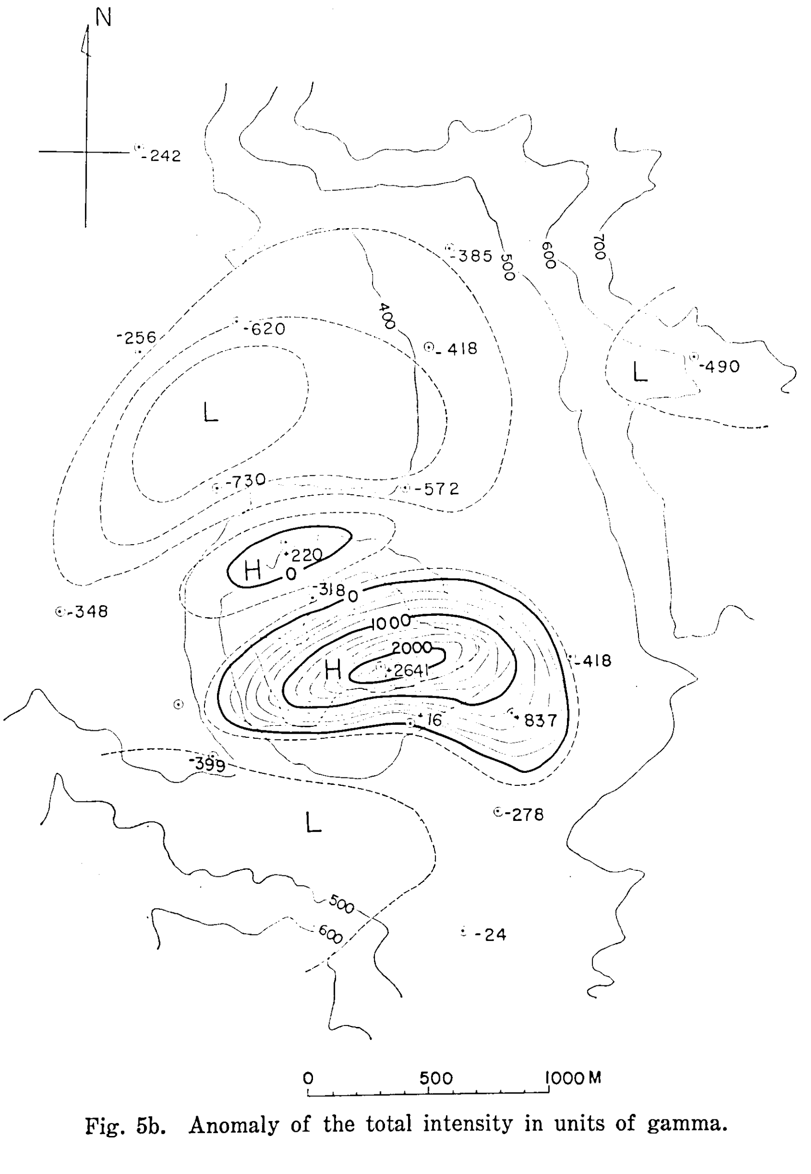

Fig. 5b. Anomaly of the total intensity in units of gamma.

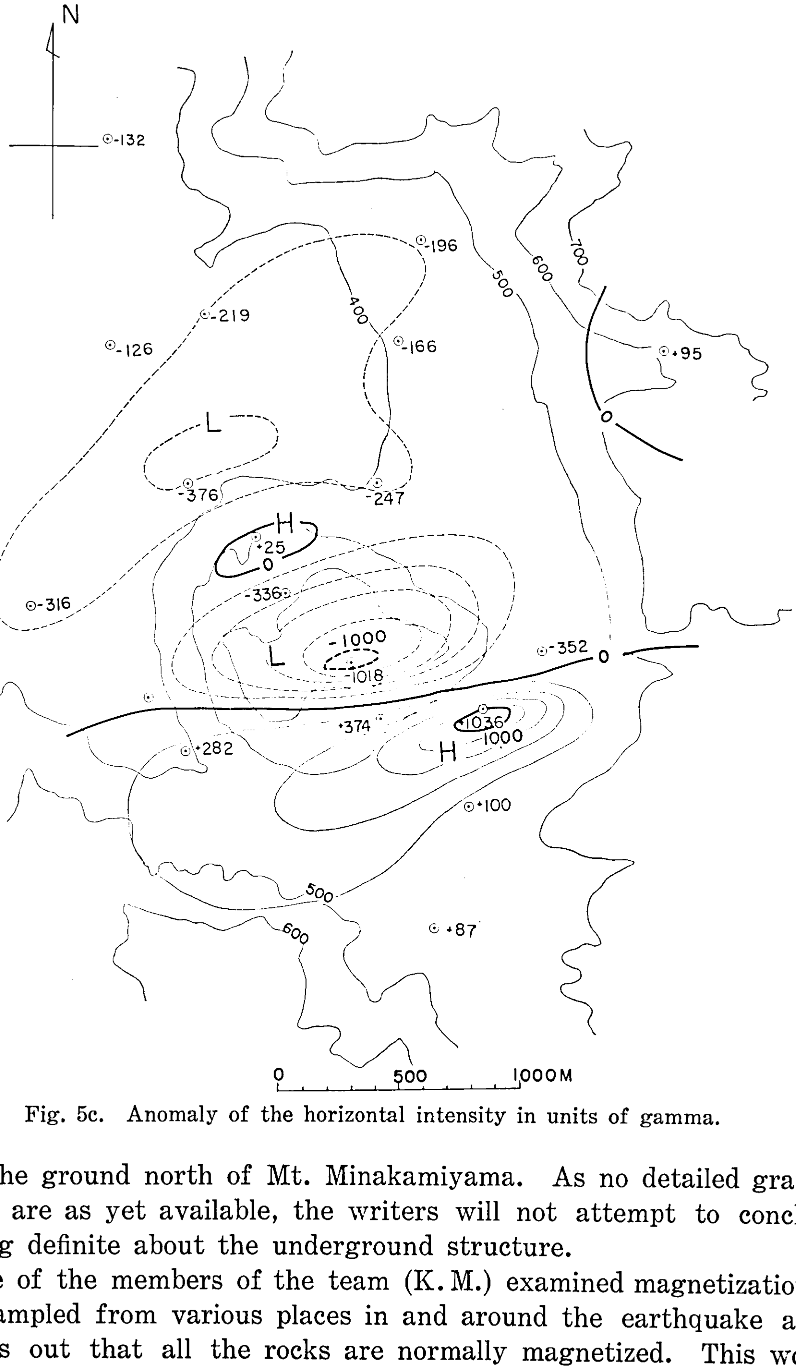

Fig. 5c. Anomaly of the horizontal intensity in units of gamma.

under the ground north of Mt. Minakamiyama. As no detailed gravity surveys are as yet available, the writers will not attempt to conclude anything definite about the underground structure.

One of the members of the team (K. M.) examined magnetization of rocks sampled from various places in and around the earthquake area. It turns out that all the rocks are normally magnetized. This would

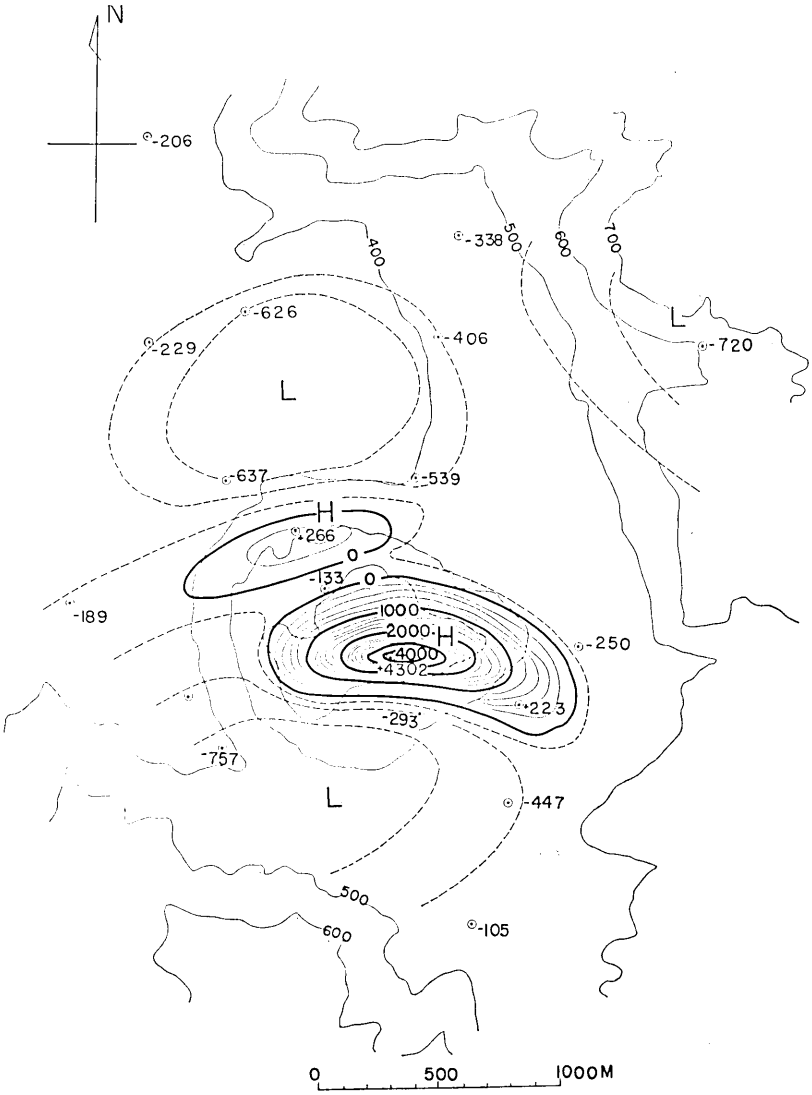

Fig. 5d. Anomaly of the vertical intensity in units of gamma.

lead to the conclusion that Mt. Minakamiyama is likely to have been formed at some time during the Pleistocene. Although no exact period as to when the mountain was formed can be inferred, the writers are inclined to suppose that its birth would be from several tens of thousand years to several hundreds of thousand years ago.

Table 6. Natural remanent magnetization of rocks sampled from Mt. Minakamiyama.

Locality	Number of specimen	Mean declination	Mean inclination	Intensity range (e.m.u./gr.)	Mean intensity (e.m.u./gr.)
Southern slope	5	N 11°19′W	59°57′	$1.43-4.93\times10^{-3}$	2.8×10^{-3}
Northern slope	5	N 7°57′W	59°59′	$1.90-3.20\times10^{-3}$	2.6×10^{-3}

4-2. Changes in the geomagnetic field during the period from Survey I to Survey II

In order to detect a local anomalous change in the geomagnetic field by repeating magnetic surveys, it is very important to occupy exactly the same point each time. For that purpose a brass peg, 50 cm in length, is buried at each station and a detailed sketch map which shows the position of the peg is prepared for each station as shown in Figs. 6a-6s. In spite of this, the peg for Station No. 10 had not been found at the time of Survey II. Care was also taken so as to make the height of the magnetometer always the same. It may be safely said that the detector coil of the magnetometer is always brought to the same position within an accuracy of 1 cm.

The values of inclination (I_M) at a station is corrected by making use of the values observed at Kanozan Geodetic Observatory (I_K) at the same instants. As we usually had several observations at a station, the mean value of I_M is taken as the typical value there at a time which is also the mean of the several observations. The mean of the inclination at Kanozan is also defined by averaging the observed values at the corresponding instants. In Table 7 are given these typical I_M, I_K and I_M-I_K values for Surveys I and II. The changes during the period from Survey I and Survey II are calculated by a formula such as

$$\delta I=(I_M-I_K)_{\mathrm{II}}-(I_M-I_K)_{\mathrm{I}}\,. \qquad (1)$$

δI's are also shown in Fig. 7 in which we see that the changes in the geomagnetic field during the period from Survey I to Survey II are small, only amounting to 1 minute of arc in the inclination. No attempt to estimate local anomalous changes in the total intensity was made because of the low accuracy of observations.

The accuracy of δI can be estimated from the argument discussed in Subsections 3-1 and 3-2. It is therefore hard to say that a marked

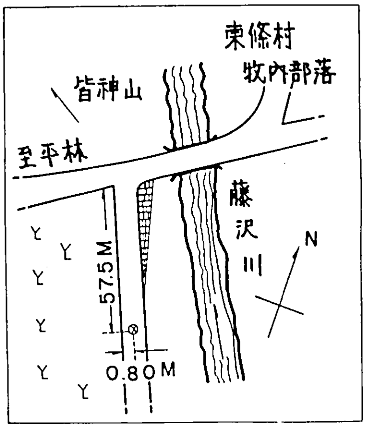

Fig. 6a. Station No. 1.

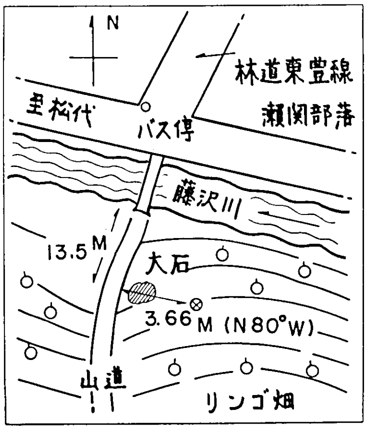

Fig. 6b. Station No. 2.

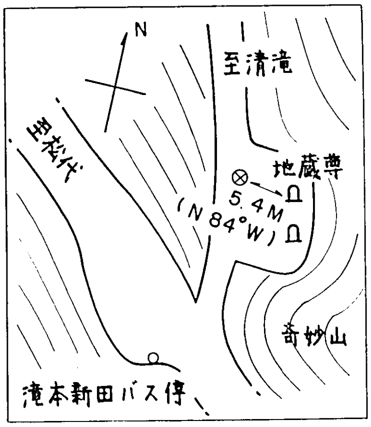

Fig. 6c. Station No. 3.

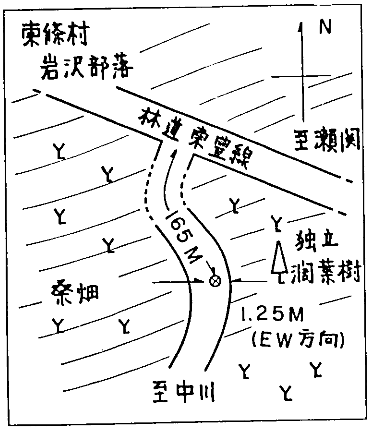

Fig. 6d. Station No. 4.

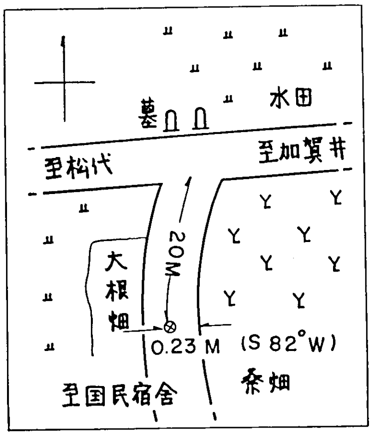

Fig. 6e. Station No. 5.

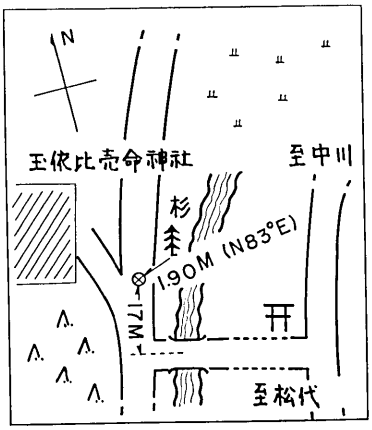

Fig. 6f. Station No. 6.

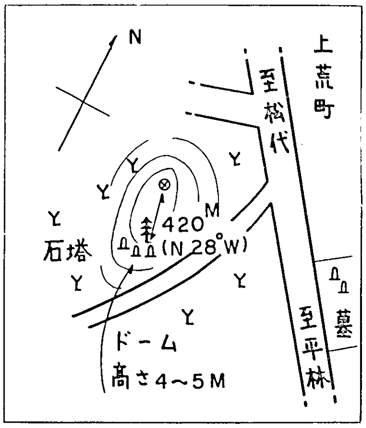

Fig. 6g. Station No. 7.

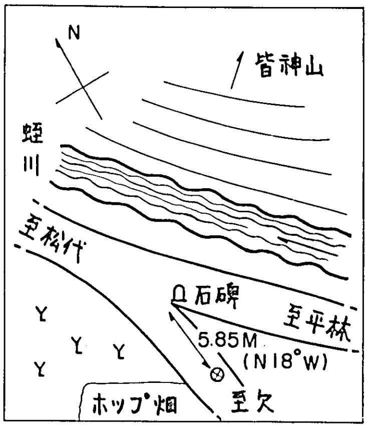

Fig. 6h. Station No. 8.

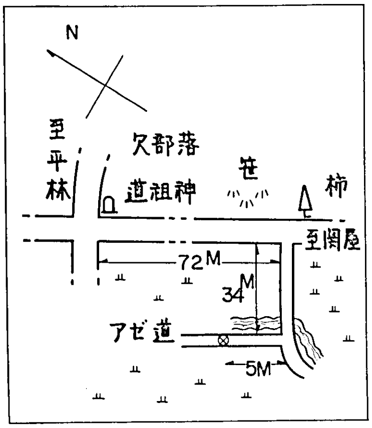

Fig. 6i. Station No. 9.

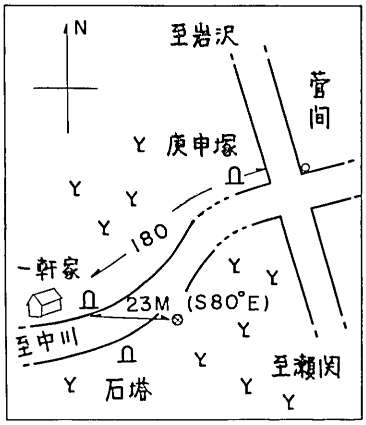

Fig. 6j. Station No. 10.

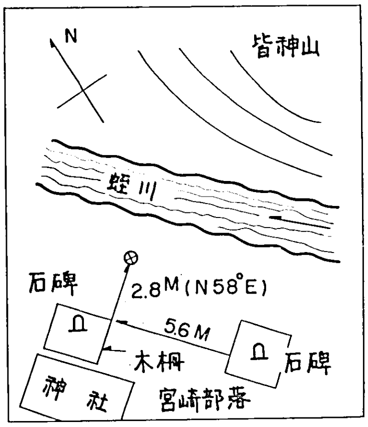

Fig. 6k. Station No. 11.

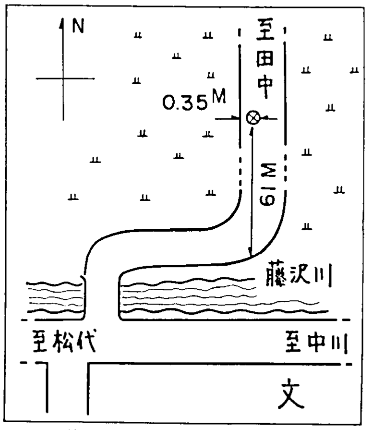

Fig. 6l. Station No. 12.

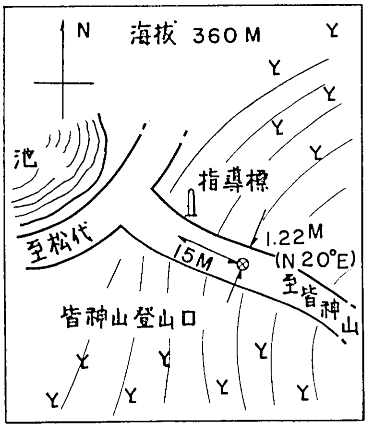

Fig. 6m. Station No. 13.

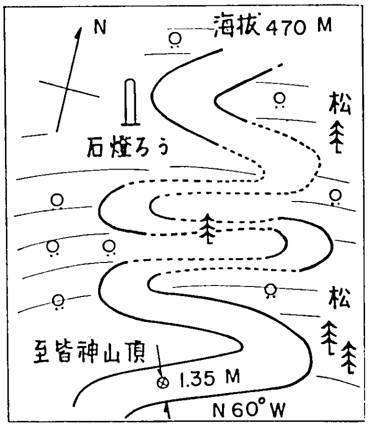

Fig. 6n. Station No. 14.

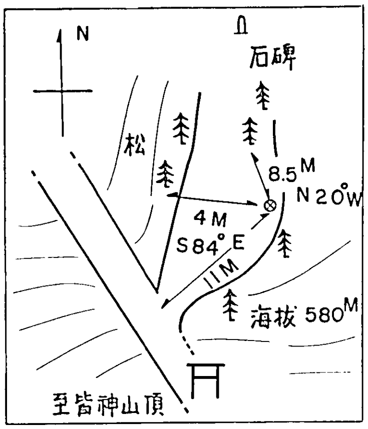

Fig. 6o. Station No. 15.

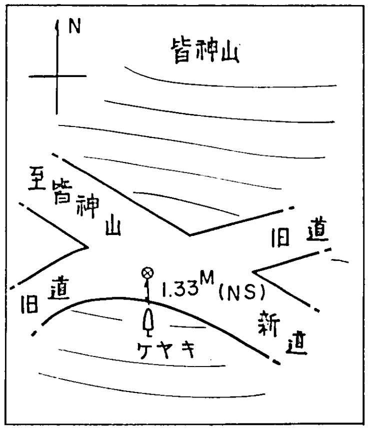

Fig. 6p. Station No. 16.

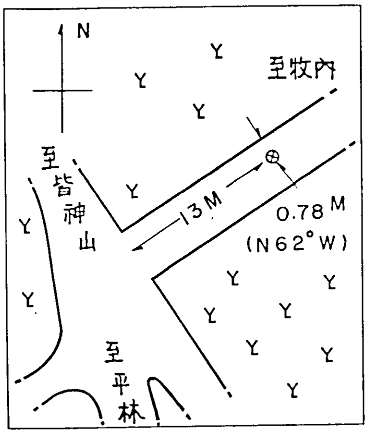

Fig. 6q. Station No. 17.

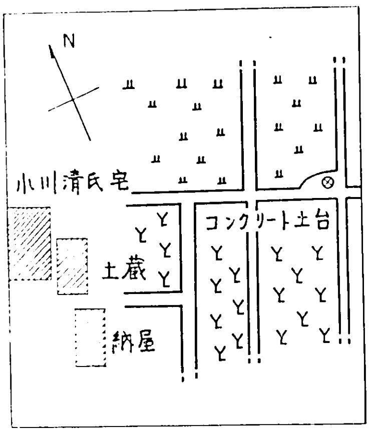

Fig. 6r. Station No. 18.

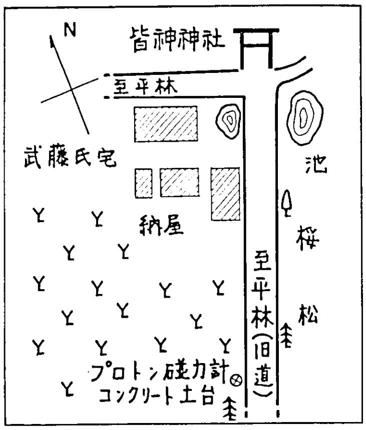

Fig. 6s. Station No. 19.

change in the geomagnetic field took place in the earthquake area during the period concerned. However, it is noticeable that the inclination indicated decreases at almost all the stations.

5. An anomalous change in earth-currents at the time of an earthquake on Nov. 23

Analysis of the earth-current observation at Station A has not been finished yet. The writers would here like to report only on an anomalous change in earth-currents at the time of a large earthquake ($M=5.0$) at 2 h 57 m JST on Nov. 23.

Prior to this earthquake, we had two big ones at 21 h 09 m and 22 h 30 m on Nov. 22. On those occasions the records showed very rapid movements of the recording pens. These movements are practically on a straight line although it is difficult to think that such impulses are caused by mechanical shocks given to the recorders. A characteristic movement of the pens was then observed at exactly the same time when the 2 h 57 m earthquake took place. As shown in Fig. 8, both the components suddenly went to one direction at the very instant of the earthquake occurrence. The recording pens then performed an impulsive motion in a direction opposite to the previous one. The pens overshot the level before the earthquake followed by a gradual relaxation-type movement lasting approximately an hour or so. Although the earth-current records have been affected by noises due to stray electric currents from railways, it was fortunate that the anomalous change occurred

Table 7. Inclination results (I_M) of the magnetic surveys.

Nos. of station	Locality		Survey I					Survey II					δI
			Date	Time	I_M	I_K	I_M-I_K	Date	Time	I_M	I_K	I_M-I_K	
1	牧内	Makiuchi	Nov. 17	13^h^50^m^	50°07.7′	47°54.0′	2°13.7′	Dec. 21	11^h^05^m^	50°06.5′	47°53.9′	2°12.6′	−1.1′
2	般若寺	Han-nya-ji	17	15 20	49 48.2	54.2	1 54.0	21	12 05	49 46.4	53.9	1 52.5	−1.5
3	滝本	Takimoto	17	16 45	49 20.9	54.2	1 26.7	21	13 15	49 19.8	54.2	1 25.6	−1.1
4	岩沢	Iwasawa	17	18 20	49 55.2	54.2	2 01.0	21	14 10	49 55.6	54.6	2 01.0	0.0
5	加賀井	Kagai	17	20 45	49 58.1	54.6	2 03.5	21	20 10	49 57.9	55.2	2 02.7	−0.8
6	中川	Nakagawa	18	9 20	49 42.3	53.7	1 48.6	21	16 05	49 43.6	54.9	1 48.7	+0.1
7	上荒町	Kamiara-machi	18	10 40	50 08.8	54.2	2 14.6	22	11 45	50 07.2	53.0	2 14.2	−0.4
8	宮崎	Miyazaki	18	11 40	49 08.1	53.7	1 14.4	22	13 30	49 07.1	53.0	1 14.1	−0.3
9	欠	Kake	18	13 20	49 49.7	53.7	1 56.0	21	9 50	49 49.3	54.0	1 55.3	−0.7
10	菅間	Sugama	18	15 40	49 49.6	53.6	1 56.0	21	15 25	49 53.5	55.0	1 58.5	(+2.5)*)
11	宮崎神社	Miyazaki Jinja	18	17 00	50 02.9	53.6	2 09.3	22	12 20	50 02.4	53.0	2 09.4	+0.1
12	田中	Tanaka	19	10 10	49 55.3	53.1	2 02.2	21	17 15	49 56.2	55.1	2 01.1	−1.1
13	大日池	Dainichi Ike	19	11 15	49 50.3	53.3	1 57.0	22	9 35	49 49.5	56.0	1 56.0	−1.0
14	皆神1	Minakami-1	19	12 15	50 10.4	53.5	2 16.9	22	10 35	50 09.8	53.4	2 16.4	−0.5
15	皆神2	Minakami-2	19	13 10	51 12.0	53.7	3 18.3	20	16 05	51 12.9	55.5	3 17.4	−0.9
16	皆神3	Minakami-3	19	15 10	49 25.5	54.5	1 31.0	22	14 30	49 24.1	53.5	1 30.6	−0.4
17	皆神4	Minakami-4	19	16 10	49 12.7	54.5	1 18.2	22	15 25	49 11.8	53.9	1 17.9	−0.3
18	平林	Hirabayashi	19	17 15	49 34.3	55.1	1 39.2	22	16 30	49 32.4	53.7	1 38.7	−0.5
19	皆神山頂	Top of Mt. Minakami	20	19 50	54 20.7	57.1	6 23.6	20	14 50	54 18.1	55.4	6 22.7	−0.9

*) The peg has been lost.

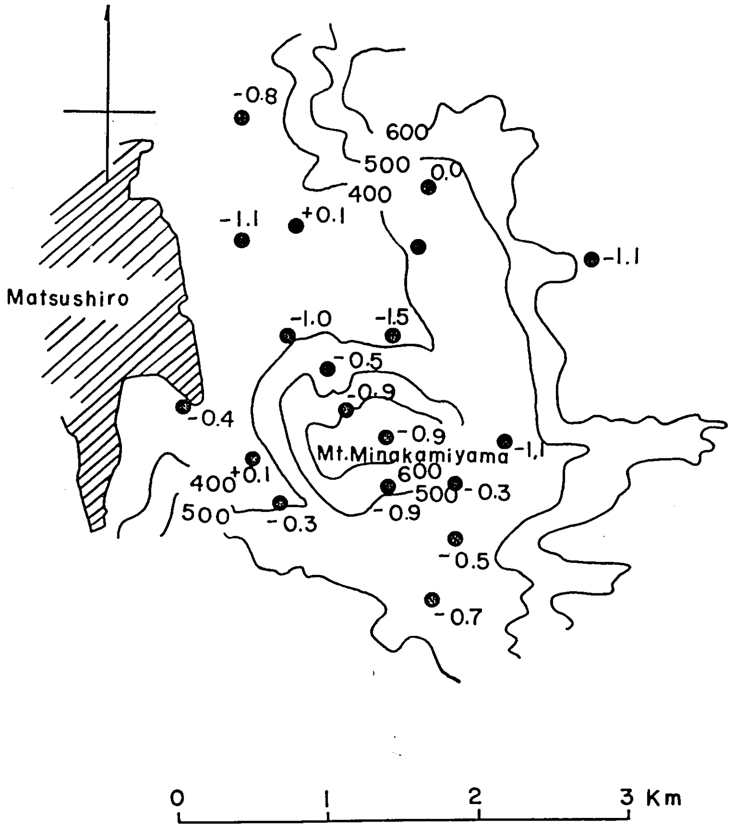

Fig. 7. Changes in the inclination during the period from Survey I to Survey II as calculated according to (1).

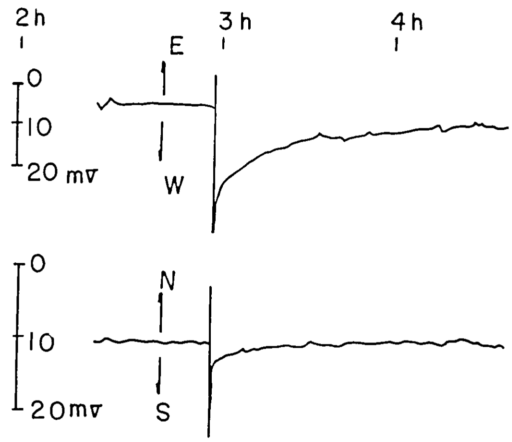

Fig. 8. Anomalous change in earth-potential at the time of an earthquake on Nov. 23.

during a mid-night period when such noises were small.

Nothing is known about the cause of such an anomalous change in earth-currents. One might suspect that it is caused by a shock given to the electrodes. If the contact between the electrodes and soil has changed, some change in the earth-potential would certainly be observed. As can be seen in Fig. 8, however, the relaxation times for the two components considerably differ from one another. It would be difficult to imagine a motion of electrode which accounts for the change in the earth-potential observed.

6. Discussion and concluding remarks

As has been argued in Section 3, it is no easy matter to distinguish possible anomalous geomagnetic changes of local origin from geomagnetic disturbances arising from non-local origins such as magnetic storm, S_q and the like. Since no other adequate way has yet been established, the differences between values of a certain geomagnetic element observed at a station in the earthquake area and those at an observatory far from the area are tentatively assumed to indicate the changes of local origin in this paper. It is obvious, however, that such a simple difference is contaminated by residual fields due to inequalities of non-local geomagnetic changes. Although the effects of such residual fields are estimated to amount to $5-10\gamma$, as already discussed in Section 3, some way to make the residual fields small should further be looked for.

One of the writers (T. R.) suggested that a systematic difference in amplitudes of geomagnetic element between various stations in Japan could be obtained provided we had a sufficiently large number of observations. If we refer to Table 4, for instance, the relation between F_M-F_K and F_K is plotted as shown in Fig. 9 which clearly indicates that, when F_K takes on a large value, F_M-F_K tends to take on a small value. In other words changes in F_K or ΔF_K are always larger than those in F_M or ΔF_M. $\Delta F_M/\Delta F_K$ can be empirically determined from the materials in Table 4. Denoting the ratio by α, fluctuation of $F_M-\alpha(F_{KO}+\Delta F_K)$ would provide an approximation for possible local changes better than that of F_M-F_K, F_{KO} being a datum value from which ΔF_K is measured. Detection of local anomalous change by a method described here will actually be made in a forthcoming paper.

In spite of the unsatisfactory accuracy of eliminating geomagnetic changes of non-local origin, the tables and figures presented in the fore-

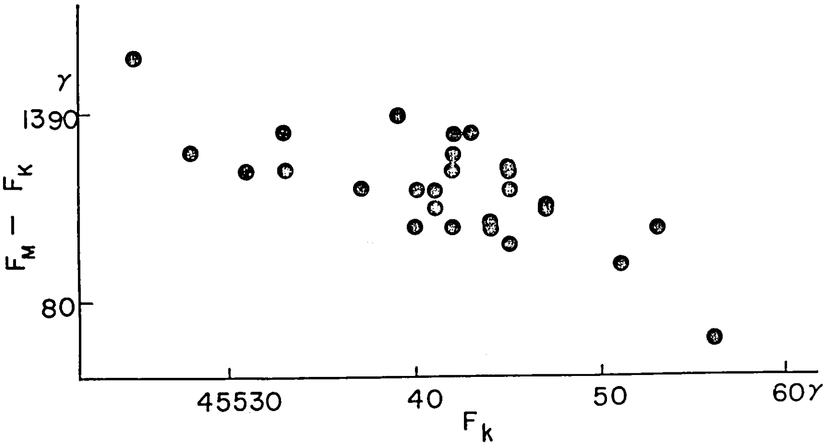

Fig. 9. Relation between $F_M - F_K$ and F_K which being taken from Table 4.

going sections would still suggest local anomalous changes of the order of 10γ that might be accompanied by the seismic activity in the Matsushiro area. If we assume that the apparent decrease in the inclination as seen in Fig. 3b towards the end of October and the beginning of November was mostly caused by a decrease in the vertical intensity (ΔZ), ΔZ should have amounted to 10−15γ. If we further imagine that the change is caused by a magnetic dipole right under the observation point, the moment of the dipole which gives rise to a 10γ change is estimated for various depths as indicated in Table 8.

Table 8. Depth and moment of the hypothetical dipole.

Depth	Moment
1 km	5.0×10^{10} e.m.u.c.g.s.
2 km	4.0×10^{11}
3 km	1.4×10^{12}
4 km	3.2×10^{12}

Although nothing certain is known why such a dipole can be produced, we first assume that magnetization of rocks decreases in association with an intrusion of hot material. Taking into consideration the fact that the magnetization of rocks composing Mt. Minakamiyama amounts to $10^{-3}-10^{-2}$ e.m.u./cm^3, it is concluded that an approximately spherical volume having a radius of a few hundred meters should lose its magnetization in order to give rise to a 10γ change at the earth's surface, the depth of the spherical volume being assumed as a few kilometers. It is therefore surmised that the temperature in a not unreasonably large volume should have exceeded the Curie point.

Outstanding magnetic changes of local origin amounting to a few tens of minutes of arc in the inclination have been experienced on the occasion of the 1950-51 eruption of Volcano Mihara[6]. Those changes have been interpreted as being caused by demagnetization and magnetization due to heating and cooling within the volcano. As an enormous amount of lava, 10^8 tons or thereabouts, welled up from the crater at that time, it may well be expected that heating on a large scale took place within the volcano. In the case of the present seismic events, only a slight upheaval of the earthquake area, say a few millimeters during a month's period, has been reported from the levelling surveys[5] and the tilt observation[7], so that it would be hard to think of an intrusion of magma of tremendous amount, only some heating by a dyke-like intrusion of magma and associated gases could be imagined.

According to a magnetic observation at Matsushiro Seismological Observatory as made by members of the Kakioka Magnetic Observatory[8], it seems likely that the difference in the vertical intensity between Matsushiro and Kakioka (36.2°N, 140.2°E) has fluctuated within a range of $10-15\gamma$ during the period studied in this paper although changes in the horizontal intensity have been so small that they hardly exceeded a few gammas. It is extremely interesting that the change in the vertical intensity towards the end of October and the beginning of November is opposite to the one which was expected from the present result of the inclination measurement. Meanwhile the absolute values of the changes are of the same order. As the distance between Station A on the summit of Mt. Minakamiyama and Matsushiro Seismological Observatory amounts to only 2 km, the opposition of sign at the two points would certainly suggest a very local nature of the change. Station A being situated at the centre of a large magnetic anomaly and the Matsushiro Seismological Observatory outside it, it might not be unreasonable to expect such an opposition of sign provided we assume that the origin of the magnetic anomaly has changed in its strength. In any case the cause of the change should be very shallow, probably 1 km or

6) T. RIKITAKE, *Bull. Earthq. Res. Inst.*, **29** (1951), 161.
7) T. HAGIWARA, Personal communication.
8) K. YANAGIHARA, Personal communication.

less, otherwise the opposition of sign cannot be accounted for.

An alternative way of interpreting the local anomalous change may be to count on a possible piezo-magnetic effect. It has been known that magnetic susceptibility as well as remanent magnetization of rocks decrease in the direction of uniaxial compression. Although experimental results are variable, a decrease rate of $\Delta J/J \sim 3\times10^{-4}$ per bar would be a typical value[9),10)]. Assuming that J amounts to 10^{-2} e.m.u./cm^3 and that a volume of 1 km^3 contributes to the change, it is estimated that a pressure amounting to some 15 bars would be required to create a magnetic moment as estimated in Table 8 for a depth of 1 km. As a stress of this order is very moderate, the possibility of explaining the change by a piezo-magnetic effect would not be unpromising. If an underground spherical cavity subjected to a uniform expansion is supposed, the ground immediately above the cavity should extend while parts of the near-surface ground a little distant from the centre should contract. It is thus expected that demagnetization and magnetization roughly in the direction of the present geomagnetic field would take place respectively above and around the cavity. Such a distribution of the local change might account for the opposition of sign observed at the two stations. In that case the depth of model cavity should be as shallow as 1 km or so because the contraction at the ground surface can be seen in the area which is distant from a point immediately above the centre of cavity by a distance comparable with the depth of the centre.

In the light of the above discussion, either intrusion of hot material or piezo-magnetic effect could be responsible for the local anomalous change in the geomagnetic field. It would seem likely that a better explanation could be provided by combining both the hypotheses. It would be premature, however, to advance an elaborate theory concerning anomalous change in the geomagnetic field of local origin on the basis of a more sophisticated model. Such a theory should be worked out after we make the nature of the local change clearer. It is very urgent to detect a change of local character more clearly at the present stage. In view of the fact that general geomagnetic changes such as magnetic storm, S_q and the like are not quite uniform over Japan, it would be desirable to make differences between a geomagnetic element observed at stations fairly close with one another. A joint work with the Kakioka Magnetic Observatory for making such differences between the changes

9) F. D. STACEY, *Nature*, **200** (1963), 1083.
10) T. NAGATA and H. KINOSHITA, *Journ. Geomag. Geoelectr.*, **17** (1965), 121.

at Station A and at the Matsushiro Seismological Observatory is now under way. We might be able to expect a better elimination of general geomagnetic changes of non-local origin and so a clearer detection of anomalous changes which are hopefully correlated to the seismic activity from such a differential work.

In conclusion the writers wish to express their sincere thanks to the local people who helped them in conducting the field work. Especially the writers would like to extend thanks to Mr. N. Muto at the shrine of Mt. Minakamiyama, Mr. K. Ogawa at the Hirabayashi Village and Messers N. Matsumoto and S. Mitsui at the Matsushiro Town Office without whose help the present work could not have been done. The writer's thanks are also due to the members of the Kanozan Geodetic Observatory who kindly offered the magnetic data at the writer's request.

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21. 松代地震群の地球電磁気学的調査 (1)

地震研究所
力武常次
山崎良雄
萩原幸男
川田　薫
沢田宗久
笹井洋一
渡部暉彦
百瀬寛一
吉野登志男
大谷和美
小沢和子
三才由子

1965年8月に始つた松代地震群に伴なうと思われる地磁気・地電流変動の観測が行なわれた．同年10～12月の期間における観測およびその結果の概略を以下に述べる．

1. 観測の概要

1-1. プロトン磁力計による観測

観測の初期に皆神山々頂の Station A に船舶用プロトン磁力計を設置したが，数日にして故障したので，11月20日頃より平林区の Station B に手動式プロトン磁力計を設置し，1日数回の観測を続けている．

1-2. GSI 二等磁気儀による観測

皆神山々頂の Station A において，10月20日～12月20日の期間，GSI 二等磁気儀による観測が実施された．常駐の観測者は1人であつたため，主として偏角および伏角のみを1日数回観測することとし，震度 IV 程度の地震を感じた場合には，観測回数を増加した．

1-3. 磁気測量

皆神山周辺の3 km×4 km の範囲に分布した19の測点について，11月17～19日および12月20～22日の2回にわたつて磁気測量を実施した.

1-4. 地電流観測

皆神山々頂に鉛管の電極を埋設し，直流増幅器つきミリボルトメーターにより地電位差変化を自記した. 電極間距離は東西 72 m，南北 64 m であつた. 期間は10月中旬より12月中旬である.

2. 地球磁場の局地的異常変化と地震活動

2-1. Station A における偏角および伏角の変動

皆神山々頂の Station A で観測された偏角ならびに伏角の値は Table 1 に記してある. 観測者が2人以上駐在した場合には，磁力の観測も行なわれたが，結果は省略する.

Station A における局地的異常変化を検出するためには，磁気嵐，日変化などの一般的変化を差引くことが必要であるが，鹿野山および伊豆大島の観測をこの目的のために利用した. しかしながら，単なる差引き計算によつて局地的変化が抽出されるとは考え難い事情がある. つまり 200 km も離れた2地点では，一般的変化といえどもかなりの差がある. Fig. 2 は皆神山の伏角値と鹿野山および伊豆大島の伏角値の差を11月3～5日の期間について示したもので，各瞬間値のばらつきは相当に大きい. しかしある1日の測定値を平均した値（これを日平均とよぶ）については，誤差は若干小さくなることが知られており，過去の経験によれば，磁力にして 10γ，角度にして 1$'$ をやや下まわる程度であるとされている.

Table 2 には皆神山，鹿野山および伊豆大島における偏角ならびに伏角の日平均値およびそれらの差を示し，Fig. 3a および 3b はそれらを図にあらわしたものである. 図に見られるように，皆神山，鹿野山および伊豆大島の変化は一見平行であるが，時としてそのいずれかにおける変化が異常の場合もある. 図の差曲線を詳細にみると，皆神山の偏角が 1.5$'$ 程度西にずれ，そのずれのはじまりの時期が11月22～23日頃の地震活動がもつともさかんであつた時期に一致する. また比較的震度の大きな地震には偏角の西偏が伴うように見える. 伏角については，10月末から11月初頭にかけて地震活動が激化した時期に，1$'$ 程度の減少があるようであるが，局地的変化検出の綜合的精度を考慮すると決定的なことはいえない.

2-2. Station B における全磁力

11月19日から12月19日の期間，平林部落で観測したプロトン磁力計による全磁力の値を Table 3 に示す. またその日平均値，鹿野山，伊豆大島の対応する時刻の日平均値，ならびにそれらの差を Table 4 に記してある.

差曲線には 5γ 程度の変動がみられるが，地震活動との対応は必ずしも明らかでない.

3. 磁気測量とその結果

観測点は Fig. 1 に示されている. 各点には真鍮棒を埋め，正確に再測できるようにした.

各測点のスケッチマップは Fig. 6a-6s に示してある.

3. 磁気異常

測量の結果は Table 5a-5s に与えられているが，磁力値は電位差計の取扱いが不備であつたので，30γ 程度の誤差がある. しかし伏角値については，0.2$'$ 以内の精度ということができる.

国土地理院発行の磁気図より地磁気要素の標準値を読取つて，磁気異常を求めた. 伏角，全磁力，水平分力および鉛直分力についての磁気異常分布は Fig. 5a-5d に示されている.

これらの図よりわかるように，皆神山はほぼ現在の地球磁場の方向に帯磁していて，その強さは，3.9×10^{-3} e.m.u./cm^3 とみつもられ，Table 6 に示す岩石試料についての実測とほぼ合致する.

さらに詳細に磁気異常を検討するならば，例えば全磁力の正異常が山頂を越えて北側にも進出していることなどから，山体の北面の帯磁が特に強いかあるいは皆神山北面に隣接した地下にもう一つの帯磁物体があることになる.

3-2. 再測によつて検知された局地的変化

Table 7 には各測点での伏角平均値および対応する時刻の鹿野山の伏角平均値を，2回の測量について示してある. また第2回と第1回との差も与えてある. この差は Fig. 7 に書きこんであるが，この2回の測量の期間に 1$'$ 程度の減少が各測点でみられる. しかし一般的変化の除去に関する精度を考えると決定的なことは何もいえない.

4. 11 月 23 日の地震に伴う地電位差異常変化

今回の地電位差観測は電車の線路よりもれる電流の影響が大きく，通常の日変化は観測できない程であつた．しかし 11 月 23 日 02 時 57 分の $M=5.0$ という地震のときには，Fig. 8 に示すような異常変化が観測された．この変化は単なる電極の震動によるものとは考えにくい点がある．

5. 謝 辞

今回の観測には現地の人々の御協力によつて種々の便宜を与えられた．特に皆神山の武藤登氏，豊栄平林区の小川清，小川久雄両氏，松代町役場総務課長松本直知，総務係長三井茂，消防本部長中西智教の三氏には何かとお世話願つたことを記して，厚く御礼を申上げたい．また地磁気観測資料については，鹿野山測地観測所の所員諸氏の御好意によるところが多い．同所員一同に感謝する．