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22. *Geomagnetic and Geoelectric Studies of the Matsushiro Earthquake Swarm* (2)

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Summary

Changes in the geomagnetic total intensity at a station in the Matsushiro earthquake area are examined. The observation by a proton precession magnetometer makes it clear that the total intensity there decreased by a few gammas during a period from Nov., 1965 to Feb., 1966. A number of short-term fluctuations in the total intensity that might be related to seismic activity are also observed.

1. Introduction

The early part of geomagnetic and geoelectric studies of the Matsushiro earthquake swarm has been reported by Rikitake et al.[1] Although some of the observations had been discontinued since around Dec. 20, 1965, a continual observation of the total geomagnetic intensity has been performed by a proton precession magnetometer at Station B (See Fig. 1 of the previous paper). This paper is aimed at reporting the results of the observation. Some discussion about change in the geomagnetic field that seem likely to be associated with seismic acitivity will also be made.

2. Results of the observation

A proton precession magnetometer of manual operation type has been at work at Station B which is situated roughly at the centre of the earthquake area. Beat frequency between proton precession signal and a 2 kc standard frequency has been recorded by a pen-writing oscillo-

1) T. RIKITAKE et al., *Bull. Earthq. Res. Inst.*, **44** (1966), 363-408.

Table 1. Total intensity values (F_M) observed at Station B

Date	Time	F_M
1965		
Dec. 20	16^h57^m	46921.1^{γ}
	59	22.2
	17 03	23.7
	19 10	22.5
	14	22.9
	16	24.8
	36	19.7
	37	23.4
	39	18.7
	41	21.5
	43	22.2
Dec. 21	9 21	32.6
	28	32.6
	32	32.8
	37	34.5
	10 40	31.2
	42	34.9
	11 18	30.9
	24	33.5
	26	31.6
	28	30.0
	31	31.6
	46	29.3
	48	29.1
	50	30.9
	13 13	24.8
	19	24.1
	21	24.8
	19 48	22.5
	50	22.2
	52	21.1
	54	23.2
Dec. 22	9 52	37.0
	54	38.2
	56	37.5
	10 51	45.0

Date	Time	F_M
1965		
Dec. 22	10^h53^m	46937.0^{γ}
	55	39.4
	11 02	40.1
	06	40.8
	47	37.0
	49	38.2
	12 11	35.2
	13	35.6
	13 15	45.0
	17	43.4
	59	37.0
	14 01	35.6
	03	34.2
	19	33.5
	21	33.5
	15 01	32.1
	49	30.0
	51	31.9
	53	26.0
	16 04	29.3
	06	30.9
	14	32.8
	16	32.8
	24	37.7
	26	37.0
	34	40.3
	36	33.5
	47	37.5
	49	37.0
	52	37.0
	54	38.9
	59	37.7
	17 03	37.7
Dec. 23	20 04	22.5
	06	20.4
	08	21.1
Dec. 24	07	27.2

Date	Time	F_M
1965		
Dec. 24	20^h09^m	46926.0^{γ}
	11	27.2
	13	27.2
Dec. 25	20 08	14.3
	10	13.3
	12	11.2
	14	13.1
	16	13.3
	33	15.9
	35	18.0
	39	16.6
	41	16.6
Dec. 26	20 01	14.0
	03	13.3
	05	14.0
Dec. 27	20 04	15.0
	06	15.0
	08	18.0
	10	19.7
Dec. 28	20 10	01.3
	12	01.3
	20	00.4
Dec. 29	20 02	19.4
	05	19.0
Dec. 30	20 07	17.3
	09	15.9
	11	16.8
	13	17.5
1966		
Jan. 1	20 38	31.2
	40	27.2
	42	28.6
Jan. 2	20 22	29.8
	24	30.5

(to be continued)

Table 1. (continued)

Date	Time	F_M
1966		
Jan. 2	20^h26^m	46930.0^{γ}
	28	32.6
Jan. 3	8 34	33.0
	36	33.0
	20 23	20.8
	26	23.7
	29	22.2
	30	30.5
	36	29.8
Jan. 4	20 02	31.4
	04	27.9
	08	28.8
	10	29.1
Jan. 5	13 56	17.8
	58	20.4
	20 06	17.8
	08	16.6
	22	18.0
	24	21.8
Jan. 6	20 08	23.9
	10	23.9
	12	24.1
Jan. 7	20 03	21.3
	05	21.1
	07	18.5
Jan. 8	19 49	19.4
	51	17.8
	53	19.6
	41	24.8
	43	25.1
	45	25.3
	47	24.8
Jan. 9	20 18	26.0
	20	19.7

Date	Time	F_M
1966		
Jan. 9	20^h22^m	46922.2^{γ}
	25	21.3
	27	20.8
Jan. 10	20 31	20.4
Jan. 11	14 20	32.6
	22	33.0
	15 17	25.5
	38	23.2
	16 22	32.8
	26	33.0
	52	29.1
	17 13	27.2
	17	26.7
	19	26.5
	19 37	22.7
	39	21.8
	41	23.2
Jan. 12	20 04	25.3
	06	24.6
	08	23.2
Jan. 13	19 31	27.6
	33	25.5
	35	27.2
Jan. 14	20 29	27.2
	31	27.2
	33	29.1
Jan. 15	20 30	22.9
	32	23.4
	34	21.1
Jan. 16	20 12	24.4
	14	25.5
	16	26.5
Jan. 17	19 32	26.5
	34	26.7

Date	Time	F_M
1966		
Jan. 17	19^h36^m	46926.9^{γ}
Jan. 18	20 30	34.5
	32	34.5
	36	35.9
	38	38.0
Jan. 19	20 02	19.9
	04	16.6
	06	19.7
Jan. 20	19 49	21.8
	53	21.8
	55	21.3
Jan. 21	20 08	22.9
	10	20.8
	12	18.5
	14	19.4
Jan. 22	20 51	13.1
	53	13.1
	55	16.6
Jan. 23	19 52	13.1
	54	12.4
	58	10.5
Jan. 24	20 52	07.0
	54	06.0
	56	05.6
	58	04.6
Jan. 25	20 16	19.9
	20	22.9
	22	21.5
	30	19.0
	31	17.3
Jan. 26	20 15	17.8
	17	16.8
	19	14.5

(to be continued)

Table 1. (continued)

Date	Time	F_M	Date	Time	F_M	Date	Time	F_M
1966			1966			1966		
Jan. 27	20^h08^m	46920.8^{γ}	Jan. 30	20^h28^m	46929.1^{γ}	Feb. 1	20^h17^m	46924.8^{γ}
	10	22.0		30	31.2	Feb. 2	13 39	24.8
	12	21.8		32	29.5		41	28.8
	14	22.0		34	29.8		45	23.7
Jan. 28	20 12	24.4	Jan. 31	20 06	19.4		49	29.3
	14	24.4		08	21.1		15 16	30.2
	16	24.1		12	20.1		18	29.8
Jan. 29	19 46	09.1	Feb. 1	20 05	25.3		24	31.4
	48	07.4		07	26.7		21 22	24.1
	50	07.0		11	26.5		24	24.6
							26	22.9

graph a few times or more a day. Actual operation has been made by Mr. H. Ogawa at Hirabayashi Village.

The results of the observation are indicated in Table 1. Those prior to the present period have already been reported in the previous paper[1].

3. Local anomalous changes in the total geomagnetic intensity at Station B

Total intensity values recorded at Kanozan and Oshima at the instants cited in Table 1 are read off from the records. Mean values for each day at Matsushiro (F_M), Kanozan (F_K) and Oshima (F_0) are calculated and tabulated in Table 2 together with F_M-F_K and F_M-F_0.

As has been discussed in the previous paper[1], it seems difficult to eliminate changes of non-local origin by making a simple difference between the values observed at two stations. It was suggested in the previous paper, however, that there is a tendency that, when F_K takes on a large value, F_M-F_K becomes small as can be seen in Fig. 9 of that paper. The fact would suggest that ΔF_M is approximately in a linear relation to ΔF_K. This is also the case for ΔF_M and ΔF_0. If we empirically determine ratios $\Delta F_M/\Delta F_K$ and $\Delta F_M/\Delta F_0$, respectively denoted by α_K and α_0, it would be natural to think that $F_M-\alpha_K F_K$ and $F_M-\alpha_0 F_0$ provide better approximations for possible local changes occurring at Matsushiro.

Taking daily mean values during a period from Nov. 19 to Dec. 19,

Table 2. Daily mean values of total intensity observed at Station B (F_M), Kanozan (F_K) and Oshima (F_0). Simple and weighted differences are also given, the latter being computed from arbitrary datum lines.

Date	F_M	F_K	F_0	F_M-F_K	F_M-F_0	$F_M-\alpha_K F_K$	$F_M-\alpha_0 F_0$
1965							
Dec. 20	46922.1$^\gamma$	45534.8$^\gamma$	46493.4$^\gamma$	1387.3$^\gamma$	428.7$^\gamma$	−0.1$^\gamma$	−3.4$^\gamma$
21	29.0	42.7	500.5	86.3	28.5	1.3	−1.9
22	36.3	48.6	510.8	87.7	25.5	4.4	−2.4
23	21.3	34.7	493.4	86.6	27.9	0.8	−4.2
24	26.7	41.2	500.3	85.5	26.4	0.4	−3.6
25	14.7	28.2	486.3	86.5	28.4	−2.9	−5.3
26	13.8	24.7	483.7	89.1	30.1	−1.3	−4.3
27	16.9	31.0	488.6	85.9	28.3	−2.6	−4.9
28	00.9	05.3	468.2	95.6	32.7	−0.6	−5.4
29	19.2	34.0	491.3	85.2	28.4	−2.4	−4.7
30	16.9	29.0	482.7	87.9	34.2	−1.2	−0.3
31	——	——	——	——	——	——	——
1966							
Jan. 1	27.0	43.3	502.0	83.7	25.0	−1.2	−5.0
2	30.7	47.0	503.3	83.7	27.4	−0.1	−2.3
3	27.6	38.0	498.1	89.0	29.5	3.2	−1.4
4	29.3	45.0	503.2	84.7	26.1	−0.1	−3.6
5	18.7	32.3	489.6	86.4	29.1	−1.7	−3.9
6	24.0	37.7	498.4	86.3	25.6	−0.2	−5.3
7	20.3	31.7	492.9	88.6	27.4	0.3	−4.8
8	22.4	38.3	——	84.1	——	−2.3	——
9	22.0	38.2	495.7	83.6	26.3	−2.6	−4.6
10	20.4	35.0	495.2	85.4	25.2	−1.9	−6.4
11	27.5	43.8	499.6	83.7	27.9	−1.0	−2.7
12	24.4	40.0	495.2	84.4	29.2	1.4	−2.4
13	26.8	40.7	497.7	86.1	29.1	0.5	−1.7
14	27.8	43.7	497.5	84.1	30.3	−0.6	−0.8
15	22.5	38.0	492.9	84.5	29.6	−1.9	−2.6
16	25.5	40.7	496.9	84.8	28.6	−0.8	−0.2
17	26.7	42.0	499.3	84.7	27.4	−0.6	−2.8
18	35.7	54.0	511.3	81.7	24.4	0.0	−3.4
19	18.7	32.7	490.8	86.0	27.9	−2.0	−4.8
20	21.6	32.7	492.8	88.9	28.8	0.9	−3.4
21	20.4	31.2	494.4	89.2	26.0	0.7	−5.8

(to be continued)

Table 2. (continued)

Date	F_M	F_K	F_0	F_M-F_K	F_M-F_0	$F_M-\alpha_K F_K$	$F_M-\alpha_0 F_0$
1966							
Jan. 22	46914.3$^\gamma$	45532.3$^\gamma$	46482.0$^\gamma$	1382.0$^\gamma$	432.3$^\gamma$	−6.1$^\gamma$	−2.5$^\gamma$
23	12.0	26.0	481.7	86.0	30.3	−4.0	−4.5
24	05.8	19.7	480.8	86.1	25.8	−5.8	−10.1
25	20.1	35.4	491.1	84.7	29.0	−2.5	−3.6
26	16.4	——	487.1	——	29.3	——	−4.3
27	21.7	34.0	492.0	87.7	29.7	0.1	−2.7
28	24.3	40.0	499.0	84.3	25.3	−1.5	−5.4
29	07.8	17.0	476.9	90.8	30.9	−1.9	−3.6
30	29.9	46.5	505.9	83.4	23.3	−0.5	−5.1
31	20.2	32.3	489.8	87.9	30.4	−0.2	−2.5
Feb. 1	25.8	38.0	496.7	87.8	29.1	1.4	−2.2
2	28.3	44.3	499.9	84.0	27.1	−3.4	−3.4

1965, the proportional constants are determined by the least square technique as

$$\alpha_K=0.702\ , \qquad \alpha_0=0.762\ .$$

Making use of these values, $F_M-\alpha_K F_K$ and $F_M-\alpha_0 F_0$ are calculated and tabulated also in Table 2. General discussion about the limitation of a method of this kind for eliminating non-local geomagnetic changes will appear in a forthcoming paper.

F_M, F_K, F_0, F_M-F_K, $F_M-\alpha_K F_K$, F_M-F_0 and $F_M-\alpha_0 F_0$ are then shown in Fig. 1 in which occurrences of relatively large earthquakes ($M=4$ or more) are also indicated with arrows. Looking at the figure, it is noticed that irregularities in the curves of F_M-F_K and F_M-F_0 are somewhat smoothed away by making use of $F_M-\alpha_K F_K$ and $F_M-\alpha_0 F_0$. One of the most striking features of the curves is the gradual decrease in F_M relative to F_K and F_0. In order to ascertain the decrease more clearly, 15-day running averages for $F_M-\alpha_K F_K$ and $F_M-\alpha_0 F_0$ are made as shown in Fig. 2. For such a procedure, it was necessary to make interpolation where the records are missing at one of the three stations. Fig. 2 clearly indicates that the decrease began to take place from the middle of December. However, the amount of decrease is different between the two curves for some unknown reason. The Oshima Magnetic Observatory being situated at the foot of an active volcano, it might not be unreasonable to think that the total geomagnetic intensity there has significantly

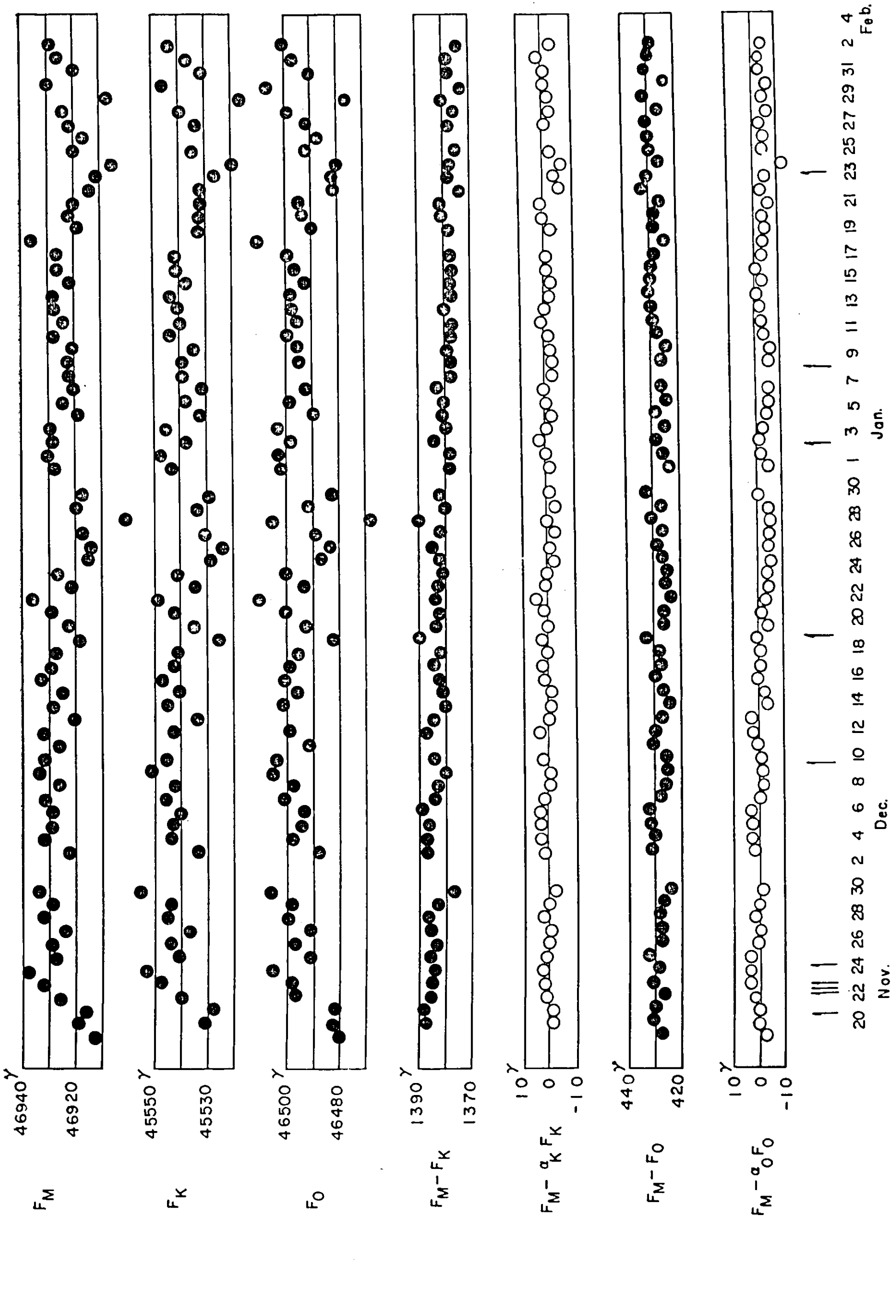

Fig. 1. Changes in F_M, F_K, F_0, F_M-F_K, F_M-F_0, $F_M-\alpha_K F_K$ and $F_M-\alpha_0 F_0$. Occurrences of large earthquakes are indicated with arrows.

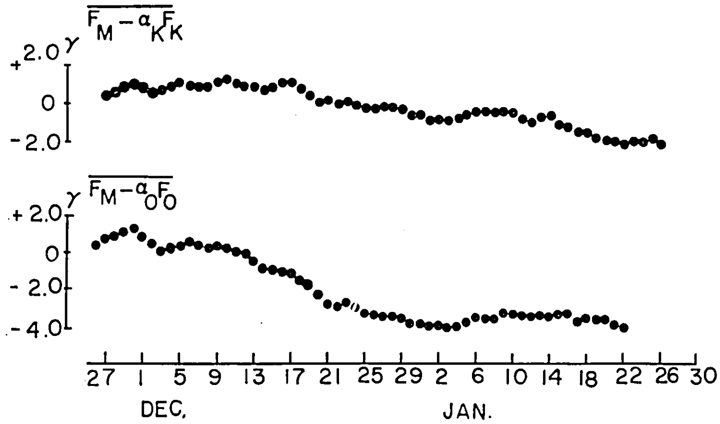

Fig. 2. 15-day running averages of $F_M - \alpha_K F_K$ and $F_M - \alpha_0 F_0$. The datum lines are arbitrary.

changed. It would certainly be said, however, that the total geomagnetic intensity at Station B has decreased by a few gammas relative to that at Kanozan and Oshima.

Apart from the above decrease, we also notice a number of short-term fluctuations amounting to the order of 5γ or so. Some of these fluctuations seem likely to be related to occurrences of earthquakes. The increase and decrease in $F_M - \alpha_K F_K$ and $F_M - \alpha_0 F_0$ at the beginning of the curves should be noticed in relation to the seismic activity towards the end of November. Meanwhile we see relatively sharp depressions around Jan. 23 when an earthquake occurred of which the magnitude was reported as being 5.1 by the Japan Meteorological Agency. But it is not quite clear how these changes in the geomagnetic field can be correlated to occurrences of earthquakes. The only thing we can safely say is the fact that no magnetic change exceeding 5γ in amplitude took place even if we assume some sort of seismo-magnetic effect. Should the amplitude of a local anomalous change be of such an order, it would be difficult to say anything definite about the possibility of seismo-magnetic effect at the present stage because of the present inadequate procedure of eliminating non-local changes.

4. Concluding remarks

A proton precession magnetometer observation conducted at a station approximately in the central area of the Matsushiro earthquake swarm makes it clear that the total geomagnetic intensity there decreased by an amount of a few gammas during a 70-day period. A number of short-term fluctuations amounting to 5γ or thereabouts in amplitude were also observed. Some of them seem likely to be associated with occurrences of relatively large earthquakes having magnitudes 4 or more although no detailed interrelation between geomagnetic change and seismic activity could be established.

In conclusion the writers are grateful to Messrs. K. and H. Ogawa with whose help they have been able to carry out the present observation. The magnetic data at the Kanozan Geodetic Observatory was made available by courtesy of the members of the Observatory to whom the writers' thanks are also due. Part of the present study was supported by a grant given by the Ministry of Education.

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22. 松代地震群の地球電磁気学的調査 (2)

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松代地震群に関連して，松代町豊栄平林区におけるプロトン磁力計による観測が継続されている．第 1 報にも述べてあるように，観測は平林区の小川久雄氏によつて手動で行われ，通常 1 日数回の観測結果が得られている． Table 1 は 1965 年 12 月 20 日から 1966 年 2 月 2 日にわたる期間の観測結果を示す．

観測の毎日の平均値を F_M とし，同時刻の鹿野山ならびに伊豆大島の全磁力値を読みとつてつくつた平均値をそれぞれ F_K および F_0 とする．簡単な差引き計算による F_M-F_K および F_M-F_0 をつくつても， 第 1 報にもすでに述べたように，地磁気の非局地的変化を完全に除去することがむずかしい．

第 1 報の Fig. 9 に示したように，ΔF_M と ΔF_K の間には経験的に比例関係がなりたつようにみえるので，$\Delta F_M/\Delta F_K$ を α_K として 11 月 19 日—12 月 19 日 の期間の資料によつて

$$\alpha_K=0.702$$

を求めた．同様に $\Delta F_M/\Delta F_0$ についても

$$\alpha_0=0.762$$

が得られた．この比例常数を使用して $F_M-\alpha_K F_K$ および $F_M-\alpha_0 F_0$ を計算し，F_M, F_K, F_0, F_M-

F_K, $F_M - F_0$ とともに Table 2 に示してある.

またこれらの量は Fig. 1 にも示してあるが，上記のような手続きによつて，単純差にみられるばらつきが若干改善されたことがわかる.

Fig. 1 について，もつとも顕著なことは，F_K, F_0 に比して F_M がきわめてゆつくり減少していることである. この点を明らかにするために，$F_M - \alpha_K F_K$ および $F_M - \alpha_0 F_0$ について 15 日間の移動平均を計算し，Fig. 2 に示してある. この結果からみて，Station B における全磁力値が観測期間中に 3～4γ の減少を示したことは疑いがない.

この長期的変化のほかに，地震活動に対応するかにみえる振巾 5γ 程度の変動があるようにみえる. 特に 11 月下旬および 1 月 23 日の震度 V の地震前後の変動は注目すべきであろう.

終りに観測を引きうけられた小川清，小川久雄両氏ならびに鹿野山測地観測所の諸氏に感謝する. この研究に要した経費の一部は文部省科学研究費による.