Study on Geomagnetic Variation of Telluric Origin

Part II. On Geomagnetic Variation Associated with Earthquakes

By

Junichiro MIYAKOSHI

Institute of Earth Science, Tottori University
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Abstract

Observational data of geomagnetic declination gathered in more than 10 years obtained at several stations, are discussed in connection with destructive earthquakes felt in the respective station. It may certainly be said that there exists correlation between the occurrence of those earthquakes and the anomalous secular change in geomagnetic declination or the time change of amplitude of daily variation of geomagnetic declination, when they are properly treated in analysis. These methods are considered to be also profitable to advance the study of an earthquake-forecast.

1. Introduction

Recently the study of earthquake-forecast has more and more earnestly been pursued to prevent and mitigate the horrible damage caused by a destructive earthquake. Especially in our country that lies on the great belt of Circum-Pacific seismic zone, the damage to human life and property caused by destructive earthquakes has from year to year been increasing in proportion with the urban developments. Consequently the problem to find any phenomena foretelling an earthquake and make it serviceable for earthquake-forecast is an important mission for the Japanese seismologist.

In our country the project on earthquake-forecast has early been investigated, and especially after the Great Kanto Earthquake, September 1, 1923, the earth crustal movement and deformation associated with destructive earthquakes have come to be investigated most in detail. At present the method of observation of the crustal deformation is considered most promising for finding an earthquake-forecast, but other methods such as an observation of very minute earthquakes as well as geomagnetic variation of telluric origin and that of earth electric current ; also that of crustal radioactivity and the like are all regarded profitable for advancement of the art of earthquake-forecast.

Concerning the study on geomagnetic variation associated with earthquake, Y. Kato published in series some papers on the local change of geomagnetic inclination as measured at a place near the epicenters of destructive earthquakes before and after their occurrences (1938, 1940, 1949, 1953). It was reported by him that the amount of change of geomagnetic inclination considered to be associated with the earthquake reached to more than $10'$ in the epicentral area. His surveys were made mainly by the dip circle or the earth-inductor at the proper yearly intervals, and continuous observations with self-recording variometer near the epicenter, were not discussed. On a continuous observation with self-recording variometer of geomagnetic declination at some seismically active areas, the provisional report was published by the present writer early in 1953 (Miyakoshi, 1953). In the paper the secular variation of geomagnetic declination continuously observed at some stations was tentatively discussed of the data of 2-3 years, on correlation with earthquake-occurrences. The present article handled the data of the same condition as in the previous paper, but much a longer period and in some detail had been treated for the purpose of detecting any connection of local, anomalous geomagnetic variation with occurrence of a destructive earthquake in the same area.

2. Instrument and Observation Stations

The variometer used for the observation of geomagnetic declination is the same as that described in the previous paper, and its main part is a simple system comprising a small magnet suspended by a long and thin metal strip. The sectional diameter, length, and magnetic moment of this suspended circular cylindrical magnet of K.S. steel is 6 mm, 55 mm and 650 c.g.s. respectively. A reflecting plane mirror of 8×15 mm is attached under the magnet nearly at its center. The system of the magnet and mirror is suspended by a thin No. 48 phosphorbronze strip of which length and torsional rigidity is 6 cm and 1.46 c.g.s./rad./cm respectively. This strip is fixed to an end of the arm of the supporting aluminium rod of 15 cm high which is also fixed to the aluminium disk with three legs. The whole system is covered air-tight, by a glass cylinder having a circular optical window of 4 cm-diameter and 4 m-focal length, at its lower part. The deflection of the mirror, caused by a variation of geomagnetic declination, is recorded as displacement of the reflected light spot on the recording photographic paper wound around the rotating cylinder of one revolution in one or two weeks, the recording equipment being at an optical distance of 4 m from the in-

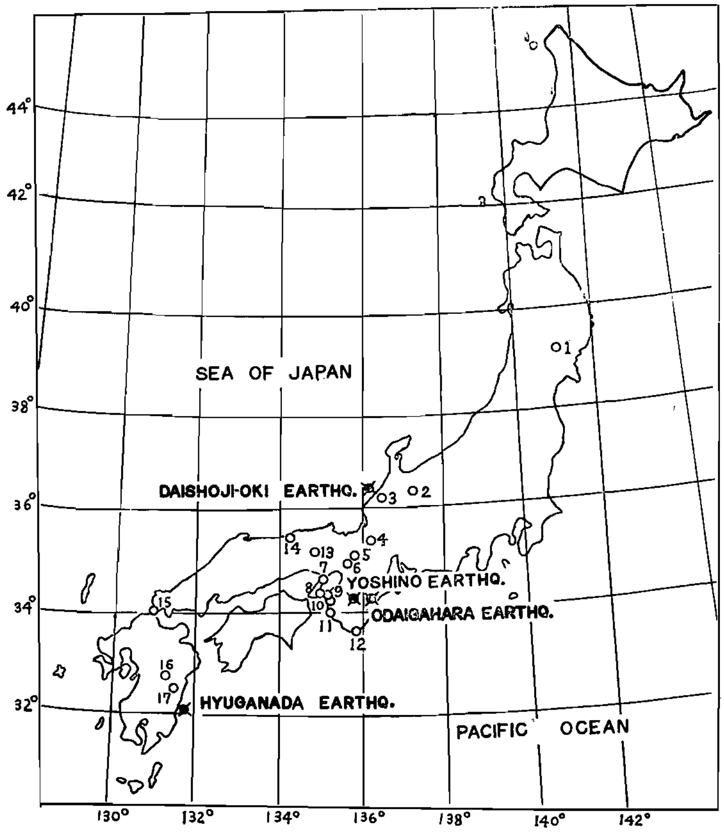

Fig. 1. Observation stations for geomagnetic declination.

(1) Hosokura (2) Kamioka (3) Ogoya (4) Tsuchikura
(5) Kamigamo (6) Abuyama (7) Ezaki (8) Naruyama
(9) Kada (10) Oura (11) Yura (12) Shionomisaki
(13) Ikuno (14) Tottori (15) Tunnel and Hinoyama
(16) Aso (17) Makimine

strument. The sensitivity of instrument is estimated, in most cases, to be nearly 0.44′/mm. The simple construction of this variometer of geomagnetic declination has some merits compared with the variometer of geomagnetic horizontal or vertical intensity. Namely, in the first place, temperature affects the value of the magnetic moment and the torsional rigidity of the suspension strip. In the usual type variometer of horizontal or vertical geomagnetic component, the moment of magnetic force exerted on the magnet is balanced with a restoring torque of twisted suspension or stretching wire. Hence both instruments are largely disturbed by temperature, unless some temperature compensation device is attached to the instruments or the observation must be made in a thermostatic room. In the second place, an observation with a variometer of horizontal or vertical geomagnetic component, is also disturbed by secular decay of the suspended magnet and creep of the suspension strip, and this effect is fatal for a continuous observation of secular geomagnetic change unless the datum value of the variometer is frequently calibrated by an absolute measurement of geomagnetic elements. Contrary to those instruments, the variometer of geomagnetic declination is little affected by these disturbances, and is safely and profitably used for observation of secular variation of geomagnetic element.

Observation stations of geomagnetic variation with the above described variometer of geomagnetic declination are 17 as shown in Fig. 1. In the present article, the observed data at the following 4 stations are selected and discussed in reference with the seismic activity in each area.

Station	Position	Height above sea-level	Depth below the ground surface	Ground rock	Initial epoch of observation	Declination for 1955.0
Makimine	λ=131°27′E φ= 32°37′N	130m	165m	Paleozoic clay slate	May, 1949	5°29′W
Yura	135°07′E 33°57′N	10	30	Mesozoic sandstone and shale	November, 1951	5°59′W
Oura	135°10′E 34°11′N	50	10	Crystalline schist	April, 1960	6°02′W
Ogoya	136°33′E 36°17′N	210	300	Tertiary tuff	July, 1948	6°46 W

The data obtained at four stations above described were treated in two ways as discussed in the following :

(A) Secular Variation

As to the secular variation of geomagnetic declination of these three stations (Oura was excluded because of a short observation period), the

Table 1-1.
OGOYA (Westward in minute)

		1~10	11~20	21~30			1~10	11~20	21~30
1949	Jan.	0.′06	0.′96	1.′66		Sept.	16.′94	16.′03	16.′08
	Feb.	2.74	4.97	4.97		Oct.	16.82	27.36	17.00
	Mar.	4.59	4.71	2.87		Nov.	17.10	17.12	17.50
	Apr.	2.48	5.61	7.77		Dec.	17.27	17.23	16.72
	May	8.23	8.98	7.90	1953	Jan.	17.35	16.78	16.69
	June	8.15	6.56	6.50		Feb.	16.16	16.56	16.94
	July	6.24	6.75	6.31		Mar.	16.94	16.81	17.06
	Aug.	6.69	5.73	4.84		Apr.	16.57	16.28	16.02
	Sept.	4.97	4.59	4.40		May	15.72	15.33	14.55
	Oct.	5.29	7.45	8.15		June	14.36	13.79	13.53
	Nov.	8.66	8.28	9.87		July	13.22	12.52	13.28
	Dec.	10.13	9.62	10.27		Aug.	13.66	13.28	13.85
1950	Jan.	10.83	10.51	11.40		Sept.	13.53	12.83	12.45
	Feb.	11.27	11.27	11.15		Oct.	14.75	14.30	15.64
1951	Oct.	11.13	11.77	11.85		Nov.	15.19	15.13	16.85
	Nov.	11.94	12.02	12.09		Dec.		16.59	16.97
	Dec.	11.79	11.80	11.81	1954	Jan.	17.10	16.97	17.87
1952	Jan.	11.78	12.08			Feb.	17.68	18.06	18.89
	Feb.		12.00	11.61		Mar.	19.65	18.89	17.48
	Mar.	12.09	12.48	12.60		Apr.	16.59	16.47	16.97
	Apr.	12.80	13.69	14.16		May	16.53	16.40	16.78
	May	14.52	14.00	13.68		June	15.51	14.49	14.24
	June	13.94	14.26	14.10		July	13.34	14.11	15.32
	July	14.54	14.81	15.12		Aug.	15.32	14.94	15.13
	Aug.	15.90	15.29	15.09		Sept.	15.19		

Table 1-2.
MAKIMINE (Westward in minute)

		1~10	11~20	21~30			1~10	11~20	21~30
1949	May		− 0′.53	0′.04		Sept.	12′.05	10′.83	10′.75
	June	0′.80	0.49	0.49		Oct.	11.31	11.05	9.82
	July	0.18	0.76	2.22		Nov.	11.00	11.45	
	Aug.	3.86	3.66	4.48		Dec.			
	Sept.	5.38	6.04	6.17	1952	Jan.			
	Oct.	5.73	5.52	6.35		Feb.			
	Nov.	7.20	7.60	7.82		Mar.			
	Dec.	7.60	7.90	8.83		Apr.			
1950	Jan.	9.50	9.00	9.06		May		10.83	11.04
	Feb.	8.97	9.12	9.27		June	11.40	12.05	12.20
	Mar.	9.32	9.00	8.30		July	11.75	13.25	12.80
	Apr.	8.61	8.67	9.64		Aug.	13.10	12.60	13.60
	May	9.51	11.00	11.00		Sept.	14.19	14.40	14.57
	June	11.00	11.00	11.35		Oct.	15.24	14.61	14.40
	July	11.20	11.30	11.80		Nov.		14.61	
	Aug.	11.25	11.40	11.45		Dec.			
	Sept.	11.70	11.70	11.75	1957	Nov.		− 0.17	0.63
	Oct.	11.65	12.13	13.20		Dec.	1.76	1.30	− 0.29
	Nov.	11.84	12.95	12.15	1958	Jan.		− 0.50	− 1.72
	Dec.	11.72	11.85	12.55		Feb.	− 2.77	− 2.68	− 1.13
1951	Jan.	12.11	11.91	12.25		Mar.	− 1.64	− 1.55	− 2.18
	Feb.	11.35	11.32	11.03		Apr.	− 1.81	− 0.55	0.25
	Mar.	11.05	10.41	10.93		May	1.47	1.30	1.13
	Apr.			9.77		June	2.93	1.26	1.18
	May	10.15	10.70	11.50		July	1.47		0.46
	June	11.55	12.40	12.01		Aug.	0.50	1.09	2.60
	July	12.52	12.23			Sept.	2.43	1.51	1.55
	Aug.		11.71	11.92		Oct.			1.39

		1~10	11~20	21~30			1~10	11~20	21~30
	Nov.	− 0′.58	− 0′.41	− 0′.79		Mar.			
	Dec.	− 2.35	− 1.67	− 3.35		Apr.		− 8′.98	−10′.07
1959	Jan.			− 4.35		May	− 8′.90	− 9.53	−10.65
	Feb.	− 4.48	− 3.19			June	− 9.82	−10.12	− 8.86
	Mar.	− 4.03	− 4.35	− 4.15		July	− 9.36	− 8.48	−10.24
	Apr.	− 5.28	− 6.16	− 5.57		Aug.	− 9.36	− 8.65	− 8.81
	May	− 5.91	− 6.20	− 8.13		Sept.	− 8.98	−10.24	− 8.60
	June	− 7.84	− 8.68	− 8.72		Oct.	− 9.44	−10.53	− 9.70
	July	− 7.34	− 5.99	− 6.16		Nov.	− 8.90	− 9.86	−10.20
	Aug.	− 5.61	− 6.66	− 7.88		Dec.	−10.20	−10.03	−11.75
	Sept.	− 8.55	− 9.77	− 9.01	1961	Jan.	−12.17	−12.25	−13.13
	Oct.	− 9.60	− 8.63	− 7.13		Feb.	−13.30	−13.22	−13.22
	Nov.	− 8.51	− 8.46			Mar.	−13.34	−14.01	−14.35
	Dec.					Apr.	−14.81	−15.52	−15.98
1960	Jan.					May	−16.57	−15.39	−15.60
	Feb.					June	−14.89		

Table 1-3.
YURA (Westward in minute)

		1~10	11~20	21~30			1~10	11~20	21~30
1951	Nov.		0′.00	− 0′.11		Aug.	− 5′.94	− 6′.51	− 7′.16
	Dec.	0′.05	0.80	0.19		Sept.	− 6.94	− 7.71	− 9.20
1952	Jan.	− 0.45	− 0.72	− 1.16		Oct.	− 9.64	− 9.80	− 9.78
	Feb.	− 1.21	− 1.34	− 1.06		Nov.	− 9.25	− 8.08	− 7.31
	Mar.	− 1.39	− 1.92	− 2.06		Dec.	− 7.06	− 7.37	− 7.35
	Apr.	− 2.42	− 3.09	− 3.72	1953	Jan.	− 6.14	− 6.44	− 6.18
	May	− 3.42	− 4.05	− 4.54		Feb.	− 5.98	− 5.46	− 5.64
	June	− 6.01	− 5.76	− 5.95		Mar.	− 5.50	− 5.79	− 6.16
	July	− 5.65	− 6.00	− 6.07		Apr.	− 5.97	− 5.67	− 5.03

		1～10	11～20	21～30			1～10	11～20	21～30
	May	− 4′.58	− 4′.99	− 5′.04		Oct.	0′.15	− 0′.03	0′.59
	June	− 5.44	− 6.06	− 6.01		Nov.	0.46	0.46	0.10
	July	− 6.59	− 6.28			Dec.	0.24	0.06	− 0.48
	Aug.			− 5.08	1956	Jan.	− 0.52	− 0.57	− 2.67
	Sept.	− 3.56	− 3.12	− 1.86		Feb.	− 2.80	− 2.62	− 2.89
	Oct.	− 1.42	− 1.06	− 1.15		Mar.	− 3.20	− 3.03	− 3.52
	Nov.	− 1.51	− 1.24	− 1.15		Apr.	− 3.79	− 3.25	− 4.37
	Dec.	− 1.06	− 0.61	− 0.48		May	− 4.31	− 3.29	− 1.19
1954	Jan.	− 0.48	− 0.48	− 0.44		June	− 0.66	− 0.30	− 0.61
	Feb.	− 0.57	− 0.39	− 0.08		July	− 0.75	− 1.19	− 1.37
	Mar.	− 0.44	− 0.93	− 0.26		Aug.	− 1.46	− 1.02	− 1.24
	Apr.	− 0.80	− 1.02	− 0.97		Sept.	− 1.24	− 3.43	− 3.87
	May	− 1.55	− 1.33	− 1.73		Oct.			− 4.23
	June	− 2.62	− 2.22	− 1.55		Nov.	− 5.17	− 4.01	− 3.38
	July	− 1.24	− 1.42	− 1.51		Dec.	− 3.29	− 3.92	− 4.05
	Aug.	− 2.22	− 2.67	− 3.34	1957	Jan.	− 4.81	− 4.81	− 3.96
	Sept.	− 3.52	− 3.65	− 3.74		Feb.	− 2.27	− 3.70	− 5.53
	Oct.	− 4.19	− 4.99	− 5.48		Mar.	− 6.91	− 7.49	− 8.03
	Nov.	− 5.39	− 4.95	− 4.77		Apr.	− 9.99		−11.72
	Dec.	− 4.54	− 4.63	− 3.87		May	−12.44	−12.88	−13.29
1955	Jan.	− 3.90	− 3.47	− 3.65		June	−14.09	−14.58	−15.94
	Feb.	− 3.61	− 3.61	− 3.83		July	−14.58	−16.59	
	Mar.	− 4.14	− 4.23	− 4.72		Aug.	−16.77	−16.55	−16.10
	Apr.	− 3.70	− 3.12	− 3.07		Sept.	−16.19	−17.13	−17.80
	May	− 2.13	− 1.46	− 1.24		Oct.	−17.66	−17.58	−18.42
	June	− 1.19	− 0.52	− 0.88		Nov.	−18.65	−19.23	
	July	− 1.24	− 0.75	− 0.79		Dec.			−20.99
	Aug.	− 0.17	− 0.21	0.41	1958	Jan.	−21.93	−21.80	−22.73
	Sept.	0.32	− 0.17	− 0.30		Feb.	−22.87		

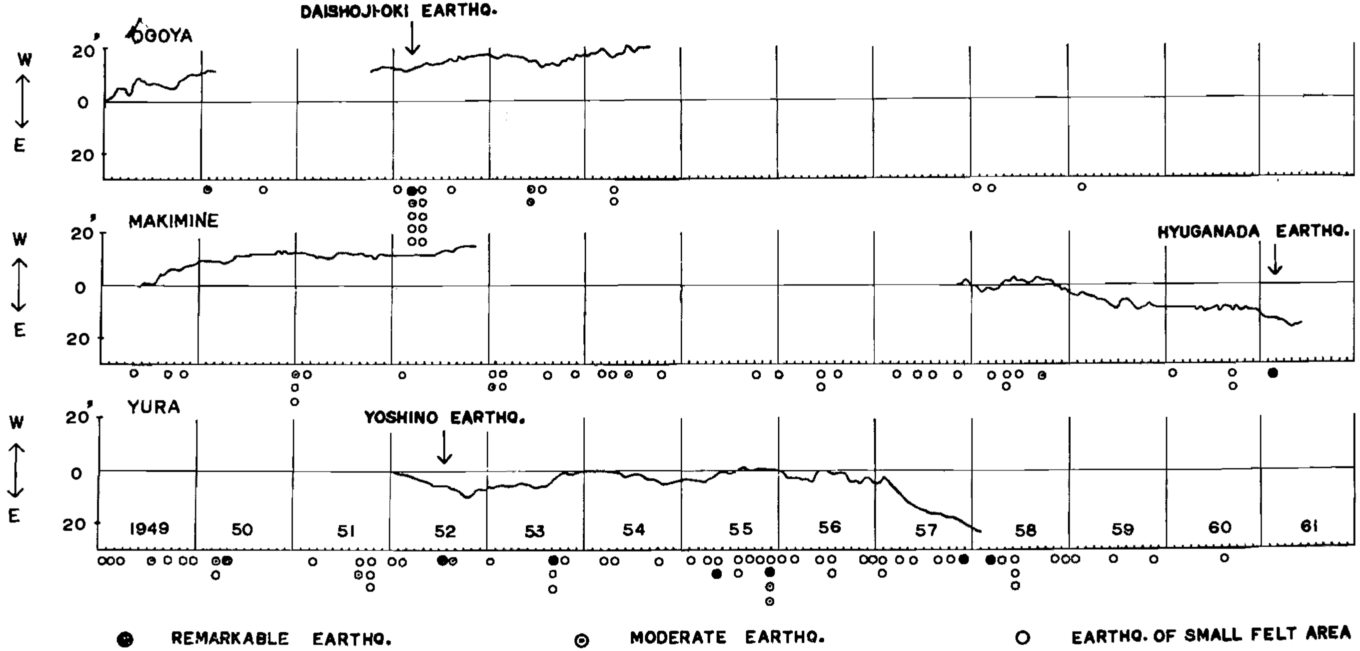

Fig. 2. Secular variation of declination observed at Ogoya, Makimine, and Yura.

declination value at O-hour on each day was read from the photographic records and then the mean values of every ten days were calculated. Ten days' average values at these stations were given in Table 1 and plotted in graphs as shown in Fig. 2.

Generally speaking the secular variation of declination observed in Japan was estimated to be 1.0′W～2.0′W per year referring to the epoch of 1955, as reported in the "Magnetic Survey of Japan, 1954-55" in the Bulletin of the Hydrographic office, vol. XV, 1960. In the present article only three stations were selected for discussion of their secular variation, but the other 14 stations which were excluded from the reason of frequent lack of observation were also available for investigation of change of geomagnetic declination in short interval of 1～2 years. As clearly seen in Fig. 2 and also ascertained by the data of other magnetic stations, the normal variation of declination, considered normal in Japan with the annual amplitude and direction of 2′W, was generally observed. But, as also distinctly be observed in Fig. 2, there was an anomalous secular variation of declination with an enormously large amplitude of nearly 10′ in a year and moreover occasionally in the eastward direction. These peculiar variations of declination observed at some stations were very interesting and profitable for the study of geomagnetic variation of telluric origin.

As to the errors caused by instrument, analysis, conditions of observation and the like, the detailed discussion was made in the previous paper (Miyakoshi, 1953). Considering various disturbances which may effect the self-recording observation of geomagnetic variation, it would safely be said that these peculiar variations, as seen in Fig. 2, could not be put down to some illusive results. Under these circumstances, the correlation between these peculiar variation and the seismic activity of the area near the station was in some detail pursued.

In Fig. 2, the earthquakes which occurred within 100 km from each station were also plotted according to their intensity grades. As seen in Fig. 2, it seemed to exist feeble correlation between seimic activity and secular variation of declination, especially with regard to strong earthquakes, but this problem should be postponed to future investigation. But concerning three destructive earthquakes of Daishoji-Oki Earthquake on March. 7, 1952, Yoshino Earthquake on July 18, 1952, and Hyuganada Earthquake on February 27, 1961, the considerably noticeable, secular variations were observed at respective three stations of Ogoya, Yura and Makimine respectively. Three earthquakes concerned were in specification as follows :

Name of Earthquake	Date of occurrence	Epi-center	Focal depth	Magnitude (Pasadena)	Distance from observation station
Daishoji-Oki	March 7, 1952	36°28′N 136°12′E	20km	7.0	40 km distant in NW from Ogoya
Yoshino	July 18, 1952	34°10′N 135°40′E	70	7.0	60 km distant in ENE from Yura
Hyuganada	February 27, 1961	32°00′N 132°00′E	10	7.0	100 km distant in SSE from Makimine

Speaking in detail, in case of Daishoji-Oki Earthquake, the geomagnetic declination observed at Ogoya showed a large westward change one month before the earthquake reaching 2′ in this one month. In this case, if simply expressed, the magnetic needle horizontally placed at Ogoya had been mar kedly deflected to the direction of the epicenter, and its motion continued until about 7 months after the earthquake reaching 6′ change in this period. Next, in the case of Yoshino Earthquake, the secular eastward variation observed at Yura commenced at the beginning of January, 1952 and continued to the end of May, 1952 ; and after a short cessation of two months, it again resumed its former speed and reached its peak on the middle of October, 1952. The total amount of eastward deflection observed during 10 months' between January to October, 1952 reached a large, eastward value of 10′. as clearly seen in Fig. 2. To describe the phenomenon comprehensively, a magnetic needle horizontally placed at Yura was seen deflect more and more in the direction of the epicenter of Yoshino Earthquake since the beginning of January or 6.5 months before the occurrence of Yoshino Earthquake, and there happened a short cessation of the change, one and half month before the earthquake. The eastward deflection of the magnetic needle, which reached the maximum point in 3 months after the earthquake-occurrence, turned its direction to W and gradually recovered from the preceding anomalous change. In case of Hyuganada Earthquake, the secular variation of declination observed at Makimine showed an anomalous eastward change of a large amount from the beginning of December, 1960, 3 months before the earthquake-occurrence and reached 4′ in 2 months, and after a cessation of one month there felt the

Hyugada Earthquake. After that, an eastward change again took place and continued to the end of April, and then turned to an westward change. In short, the magnetic needle horizontally placed at Makimine began to deflect to the direction of the epicenter of Hyuganada Earthquake 3 months before the earthquake, and after a cessation of change of one month before the earthquake, it was again deflected to E, reaching the maximum deflection of 6′ at the end of April. There should be mentioned that the mode of secular, anomalous change of declinations observed at two places of Yura and Makimine which were considered to be associated with two destructive earthquakes, showed a good resemblance as seen in Fig. 2. From these results, the problem on correlation of occurrence of a destructive earthquake with an anomalous change of geomagnetic element was considered to be worth investigation, and would throw a beam of hope, in near future, for the study of earthquake-forecast and nature of earthquakes.

(B) Variability of Daily Variation

Variability of the daily variation of geomagnetic elements began to be discussed by M. Hasegawa and M. Ōta since early 1936. And the recent report by Hasegawa (1960) reviewed the present knowledge on the variability of Sq foci. From these investigation and other observed data it was concluded generally that the ratio of the amplitude of daily variation of declination between 2 stations of slightly different longitude and latitude, say 3.5° in longitude and 1.5° in latitude, has been nearly 1.05, and its variability of day to day was estimated to be within 5%. Under these circumstances the amplitude ratio of observed daily variation of declination at 2 stations were calculated during several months referring to strong earthquakes, having their epicenter in the area of one of the selected stations. Namely the data at two combinations of Makimine and Yura during the period of March 11-Oct. 13, 1952, and of Makimine and Oura during the period of Sept. 6, 1960-May 14, 1961, referring to the destructive earthquake of Yoshino (July, 18, 1952) and two strong earthquakes of Ōdaigahara (Dec. 26, 1960) and Hyuganada (February 27, 1961) respectively.

In case of Yoshino Earthquake (already referred), the ratios of amplitude of daily variation observed at Makimine to that of Yura were discussed. In this case, besides the daily variation, the short period variation was also examined, and short period variation meant the variation of bay-

Tabl 2-1. Case of Yoshino Earthquake (Short Period Variation).

M/Y: Makimine/Yura

R.M.: Running Mean of 15 Days

Mar. 1952			Apr.			May			June		
Date	M/Y	R.M.	Date	M/Y	R.M.	Date	M/Y	R.M.	Date	M/Y	R.M.
1			1		0.94	1			1		0.99
2			2			2	0.93		2		0.96
3			3			3			3		0.96
4			4			4	0.91		4		0.98
5			5			5			5		0.99
6			6	0.98		6			6		1.01
7			7	0.99		7			7		0.96
8			8	0.93		8			8	1.20	
9			9			9			9	0.78	
10			10			10			10		
11			11			11			11	1.00	
12	1.10		12			12			12		
13	1.03		13			13			13		
14			14			14			14	1.07	
15			15			15			15	0.76	0.93
16			16			16			16		0.91
17	1.00		17			17			17	0.86	0.93
18			18			18	0.90		18		
19	0.81	0.97	19			19	0.99		19		0.92
20		0.94	20			20	0.82		20		
21	0.97	0.93	21			21			21		
22	0.98		22			22			22	0.82	0.89
23			23			23			23	1.10	0.94
24	0.95	0.93	24			24			24		
25	0.90	0.92	25			25		0.93	25		0.93
26	1.00		26			26	0.91	0.93	26		
27	0.82	0.94	27			27	0.93	0.91	27		0.94
28			28			28	0.91	0.94	28		
29		0.93	29			29	0.99		29		
30		0.93	30			30			30	0.99	0.97
31		0.94				31					

July			Aug.			Sept.			Oct.		
Date	M/Y	R.M.	Date	M/Y	R.M.	Date	M/Y	R.M.	Date	M/Y	R.M.
1		0.93	1			1	0.85	0.99	1		
2	0.83	0.96	2	1.01	1.05	2	1.01	0.98	2		0.96
3		0.96	3		0.99	3	1.05	0.99	3	1.00	0.96
4	0.96	0.96	4		0.99	4		0.98	4		0.98
5		0.98	5			5			5	0.89	0.99
6			6		1.01	6			6	0.94	
7		0.96	7	0.91		7	1.00	0.99	7	1.09	
8		0.95	8		1.01	8	0.88	0.98	8		
9	1.03	0.92	9			9	0.90	0.96	9	0.88	
10	0.96		10	0.96	0.99	10	1.03	1.01	10		
11	1.10		11			11		1.00	11	1.08	
12		0.93	12			12			12	1.03	
13		0.91	13	1.10	0.96	13			13		
14	0.82	0.92	14			14	1.08	0.99	14		
15	0.92	0.93	15		0.98	15		0.99	15		
16	0.70	0.93	16			16	1.00	1.01	16		
17		0.93	17		0.99	17	1.09	1.03	17		
18		0.96	18			18		1.02	18		
19		0.96	19			19		0.99	19		
20	0.82		20	0.87	1.01	20			20		
21	1.06		21		0.99	21	0.95	0.99	21		
22		1.01	22			22		0.97	22		
23	1.00	0.99	23			23		0.98	23		
24		1.02	24	1.00	1.01	24		0.98	24		
25	1.01		25		0.98	25	1.00		25		
26	1.29	1.03	26		0.98	26	0.85	0.97	26		
27	1.00		27	1.08	0.99	27			27		
28		1.06	28		1.01	28	1.00	0.96	28		
29		1.06	29			29	0.88	0.96	29		
30			30			30	1.07	0.97	30		
31	0.97	0.04	31	1.07	1.01				31		

Table 2-2. Case of Yoshino Earthquake (Diurnal Variation).

M/Y: Makimine/Yura

R.M.: Running Mean of 15 Days

Mar. 1952			Apr.			May			June		
Date	M/Y	R.M.	Date	M/Y	R.M.	Date	M/Y	R.M.	Date	M/Y	R.M.
1			1		0.98	1	1.00		1	1.04	1.00
2			2		0.98	2	0.85		2		1.00
3			3			3			3	0.88	1.00
4			4			4			4	0.96	1.01
5			5			5			5	0.91	0.99
6			6			6		0.97	6	0.96	0.99
7			7			7		0.96	7		0.97
8			8			8		0.96	8		0.97
9			9			9		0.96	9		0.96
10			10			10		1.00	10		0.97
11			11			11		0.99	11	0.98	0.99
12	0.98		12			12		0.98	12	0.98	0.99
13			13			13	1.01	0.98	13	1.03	1.00
14	0.96		14			14	0.96	0.99	14		1.00
15			15			15		0.99	15		1.00
16	1.03		16			16	1.03	0.99	16	0.98	1.03
17			17			17		0.99	17	1.05	1.01
18	1.05		18			18	0.93	0.99	18		1.01
19	1.03	1.04	19			19	0.97	0.99	19		1.02
20	1.07	1.04	20			20	0.96	0.97	20		1.03
21	1.17	1.03	21			21	1.02	0.99	21		1.03
22		1.04	22			22		0.99	22		1.04
23		1.02	23			23		1.01	23	1.18	1.04
24		1.03	24			24		1.01	24	0.91	1.02
25		1.03	25			25		1.01	25	1.04	1.01
26	1.05	1.02	26			26		1.03	26		0.99
27	0.92	1.02	27			27	0.86	1.01	27		0.99
28	0.99	1.01	28			28	1.17	1.01	28		0.99
29		0.98	29	1.01		29	1.05	1.00	29	1.05	0.99
30	0.93	0.96	30			30	1.15	1.00	30		0.99
31		1.03				31		1.00			

July			Aug.			Sept.			Oct.		
Date	M/Y	R.M.	Date	M/Y	R.M.	Date	M/Y	R.M.	Date	M/Y	R.M.
1	0.89	0.95	1	0.93	0.96	1			1	1.03	0.99
2	0.98	0.97	2	0.97	0.96	2			2	1.01	0.98
3	0.88	0.96	3	0.93	0.96	3			3	0.95	0.97
4	0.97	0.99	4	1.01	0.95	4			4		
5		0.99	5		0.96	5			5		
6		0.99	6		0.96	6			6		
7		0.99	7		0.96	7	0.95		7	1.00	
8		0.99	8	0.96	0.96	8			8	1.01	
9	1.05	1.00	9	0.89	0.97	9			9	0.93	
10	1.01	1.00	10	0.96	0.97	10			10	1.06	
11	1.04	1.01	11	0.97	0.98	11	1.03		11		
12		1.01	12	0.96	0.97	12			12		
13	1.08	1.04	13		0.97	13			13		
14	1.00	1.04	14		0.97	14		1.01	14		
15		1.04	15	1.05	0.97	15	1.07	1.04	15		
16	0.96	1.04	16	0.99	0.97	16		1.03	16		
17	0.98	1.04	17		0.99	17		1.04	17		
18		1.04	18		0.99	18		1.04	18		
19	1.00	1.04	19		1.00	19		1.05	19		
20	1.20	1.04	20			20		1.05	20		
21		1.04	21			21		1.01	21		
22		1.01	22			22	1.04	1.01	22		
23		1.01	23			23	0.99	1.00	23		
24		1.04	24			24	1.07	1.00	24		
25		1.01	25			25	1.08	1.01	25		
26		1.01	26			26		1.00	26		
27	1.02	1.00	27			27		1.00	27		
28		0.97	28			28	0.81	1.00	28		
29	0.93	0.97	29			29		1.00	29		
30		0.97	30			30		0.99	30		
31		0.97	31						31		

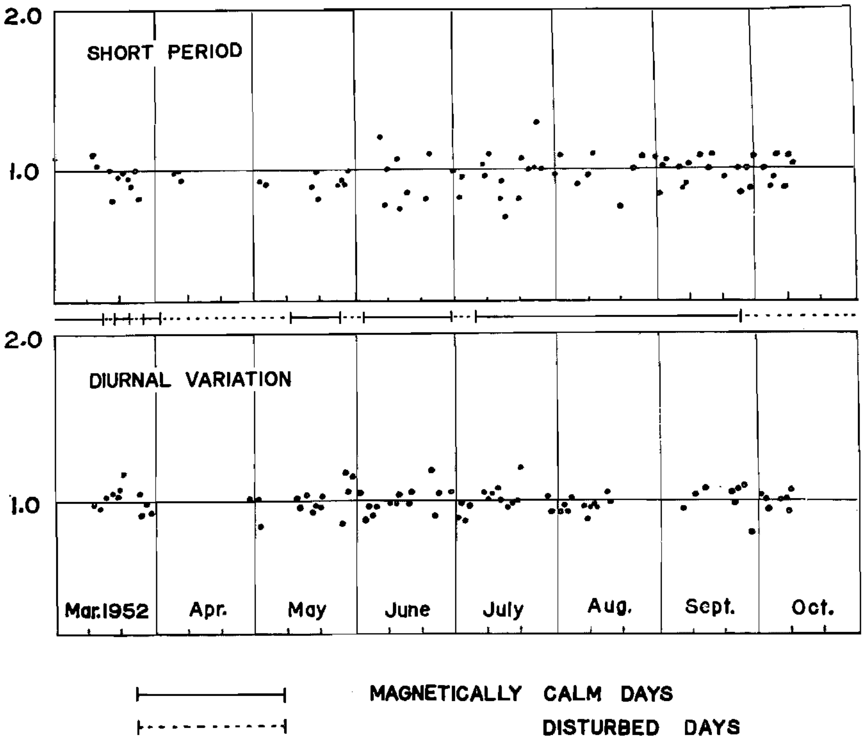

Fig. 3. Amplitude ratio of magnetic variation (Makimine/Yura).

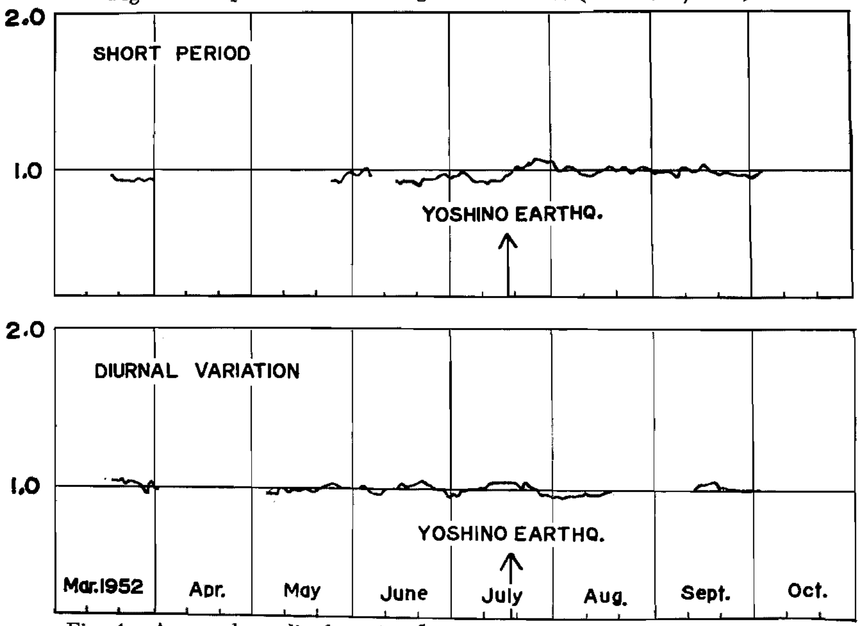

Fig. 4. Averaged amplitude ratio of magnetic variation (Makimine/Yura).

Table 3-1. Case of Odaigahara and Hyuganada Earthquakes (Short Period Variation).

M/O: Makimine/Oura

R.M.: Running Mean of 15 Days

Sept. 1960			Oct.			Nov.			Dec.			Jan. 1961		
Date	M/O	R.M.	Date	M/O	R.M.	Date	M/O	R.M.	Date	M/O	R.M.	Date	M/O	R.M.
1			1	1.61	1.39	1	1.35	1.61	1	1.86	1.55	1		
2			2	1.32	1.43	2			2	1.27	1.58	2		
3			3	1.66	1.43	3			3			3		
4			4			4			4			4		
5			5	1.47	1.48	5	1.69	1.63	5			5		
6			6	1.43	1.48	6			6			6	1.36	1.50
7	1.09		7	1.45	1.48	7			7	1.72	1.52	7		
8	1.09		8	1.47	1.49	8			8	1.36	1.49	8		
9	1.19		9	1.54	1.48	9			9			9	1.57	1.39
10	1.07		10			10			10	1.53	1.47	10		
11			11	1.49	1.44	11			11			11		
12	1.00		12			12			12	1.25	1.47	12		
13	1.42		13			13	1.78	1.64	13	1.53	1.47	13		
14	1.27	1.20	14			14	2.00	1.65	14			14		
15			15			15	1.45	1.57	15	1.33	1.44	15		
16			16			16	1.33	1.57	16	1.46	1.46	16	1.24	1.51
17			17			17			17			17		
18	1.41	1.22	18	1.25	1.67	18			18			18	1.13	1.37
19			19	1.25	1.66	19			19			19		
20			20	1.95	1.60	20			20			20	1.08	1.13
21			21	1.38	1.55	21	1.64	1.53	21			21		
22	1.00	1.20	22			22	1.21	1.53	22	1.47	1.44	22	1.51	1.18
23			23			23			23	1.60	1.45	23		
24	1.19	1.28	24	2.43	1.64	24			24			24	0.97	1.16
25			25	1.95	1.62	25	1.26	1.55	25			25	1.02	1.16
26	1.43	1.32	26	1.40	1.65	26	1.84	1.55	26	1.38	1.48	26	1.27	1.17
27	0.97	1.32	27	1.26	1.69	27			27			27		
28			28	1.81	1.67	28			28	1.42	1.48	28		
29			29	2.16	1.69	29	1.74	1.53	29			29		
30	1.34	1.39	30	1.40	1.69	30			30			30		
			31	1.49	1.69				31	1.56	1.44	31		

Feb.			Mar.			Apr.			May		
Date	M/O	R.M.	Date	M/O	R.M.	Date	M/O	R.M.	Date	M/O	R.M.
1			1			1	1.19	1.13	1		
2			2			2	1.10	1.13	2		
3	1.22	1.26	3			3			3		
4			4			4			4		
5	1.25	1.36	5			5			5	1.14	1.25
6			6	1.32	1.23	6			6	1.05	1.26
7	1.31	1.57	7			7	0.71	1.21	7		
8			8			8	1.37	1.24	8		
9			9			9			9		
10			10	1.13	1.18	10			10		
11	1.64	1.31	11			11			11		
12			12			12			12		
13			13			13			13		
14	1.30	1.20	14			14	1.69	1.22	14		
15			15	1.31	1.09	15	1.37	1.28	15		
16	1.24	1.30	16	1.10	1.01	16	1.02	1.33	16		
17	1.29	1.30	17	1.01	1.07	17	1.13	1.11	17		
18	1.13	1.30	18			18			18		
19			19			19			19		
20	1.22	1.24	20	0.99	1.07	20			20		
21			21			21			21		
22			22	0.94	1.09	22	1.11	1.17	22		
23			23	1.24	1.06	23			23		
24			24	0.81	1.05	24	1.32	1.16	24		
25			25			25			25		
26			26			26			26		
27			27			27	0.99	1.16	27		
28			28	1.32	1.10	28	1.22	1.16	28		
29			29			29			29		
			30			30			30		
			31						31		

Table 3-2. Case of Odaigahara and Hyuganada Earthquakes (Diurnal Variation).

M/O: Makimine/Oura

R.M.: Running Mean of 15 Days

Sept. 1960			Oct.			Nov.			Dec.			Jan. 1961		
Date	M/O	R.M.	Date	M/O	R.M.	Date	M/O	R.M.	Date	M/O	R.M.	Date	M/O	R.M.
1			1			1			1			1	1.95	1.47
2			2			2	1.29	1.39	2			2	1.61	1.46
3			3	0.85	1.20	3			3			3	1.63	1.46
4			4	1.42	1.25	4			4	1.62	1.43	4	1.40	1.44
5			5			5			5			5	1.66	1.45
6			6			6	1.35	1.41	6			6		
7	1.04		7			7	1.31	1.44	7	1.41	1.39	7	1.02	1.44
8	1.05		8			8	1.27	1.44	8			8	1.21	1.44
9	1.17		9	1.56	1.33	9	1.84	1.44	9	1.58	1.44	9	1.45	1.39
10	0.99		10	1.42	1.29	10	1.54	1.45	10			10		
11	0.99		11	1.39	1.32	11			11	1.38	1.44	11	1.14	1.28
12	1.03		12			12			12			12	1.47	1.26
13			13			13			13	1.80	1.40	13		
14	1.27	1.14	14			14			14	1.28	1.40	14	1.16	1.22
15	1.39	1.13	15	1.66	1.45	15			15	1.03	1.40	15	1.39	1.21
16			16	1.09	1.29	16			16			16		
17	1.19	1.13	17	0.92	1.24	17			17			17	1.27	1.19
18	1.15	1.13	18	1.13	1.22	18			18			18	0.92	1.18
19	1.25	1.14	19	1.15	1.20	19			19			19	1.17	1.16
20			20			20	1.31	1.24	20	1.34	1.39	20		
21			21			21			21			21	1.17	1.15
22	1.00	1.11	22	1.27	1.20	22			22			22	0.95	1.11
23	1.11	1.11	23	1.30	1.15	23	1.17	1.24	23	1.23	1.41	23		
24	1.06	1.11	24	1.05	1.16	24			24			24	1.22	1.13
25	1.05	1.10	25			25			25	1.63	1.46	25	1.12	1.11
26	1.04	1.07	26			26			26	1.37	1.48	26	1.08	1.13
27	1.16	1.09	27			27			27	1.47	1.49	27		
28			28			28			28	1.31	1.50	28	1.16	1.13
29	1.10	1.09	29			29	1.21	1.34	29	1.50	1.51	29	1.49	1.13
30	1.10	1.10	30	1.25	1.25	30	1.39	1.36	30			30	1.03	1.13
			31						31	1.36	1.48	31	0.97	1.13

Feb.			Mar.			Apr.			May		
Date	M/O	R.M.	Date	M/O	R.M.	Date	M/O	R.M.	Date	M/O	R.M.
1	1.08	1.13	1			1	1.08	1.06	1		
2	1.21	1.13	2	1.22	1.15	2			2		
3			3	1.14	1.16	3			3	1.00	1.04
4	1.07	1.14	4			4	0.97	1.06	4	1.03	1.03
5			5	1.18	1.13	5			5		
6	1.07	1.16	6			6	1.02	1.09	6		
7	1.12	1.16	7	1.18	1.13	7	1.12	1.07	7		
8	1.13	1.14	8	1.03	1.21	8	1.19	1.08	8		
9	1.20	1.15	9	1.24	1.18	9			9		
10			10	1.23	1.17	10			10	1.08	1.10
11			11			11			11	1.15	1.11
12	1.28	1.16	12	0.91	1.09	12			12	1.13	1.11
13			13	1.03	1.09	13	1.12	1.06	13	1.32	
14	1.49	1.16	14	1.17	1.08	14	1.07	1.06	14	0.97	
15	1.00	1.17	15	0.94	1.07	15			15		
16	0.88	1.16	16	1.12	1.06	16	0.97	1.04	16		
17	1.23	1.16	17	1.07	1.04	17			17		
18			18			18			18	1.09	
19	1.21	1.16	19			19			19	1.05	
20	1.12	1.14	20			20	0.97	1.06	20		
21	1.17	1.13	21	1.03	1.05	21	1.03	1.06	21		
22	1.06	1.10	22	0.93	1.04	22	1.07	1.04	22		
23			23	1.16	1.06	23	1.06	1.04	23		
24			24			24			24		
25			25	1.16	1.05	25			25		
26	1.10	1.03	26	1.02	1.05	26	1.18	1.03	26		
27	1.15	1.13	27			27	1.05	1.03	27		
28	1.09	1.02	28	0.92	1.04	28	1.11	1.04	28		
29			29	1.03	1.05	29	0.90	1.04	29		
			30	1.17	1.05	30	0.93	1.04	30		
			31	1.00	1.05				31		

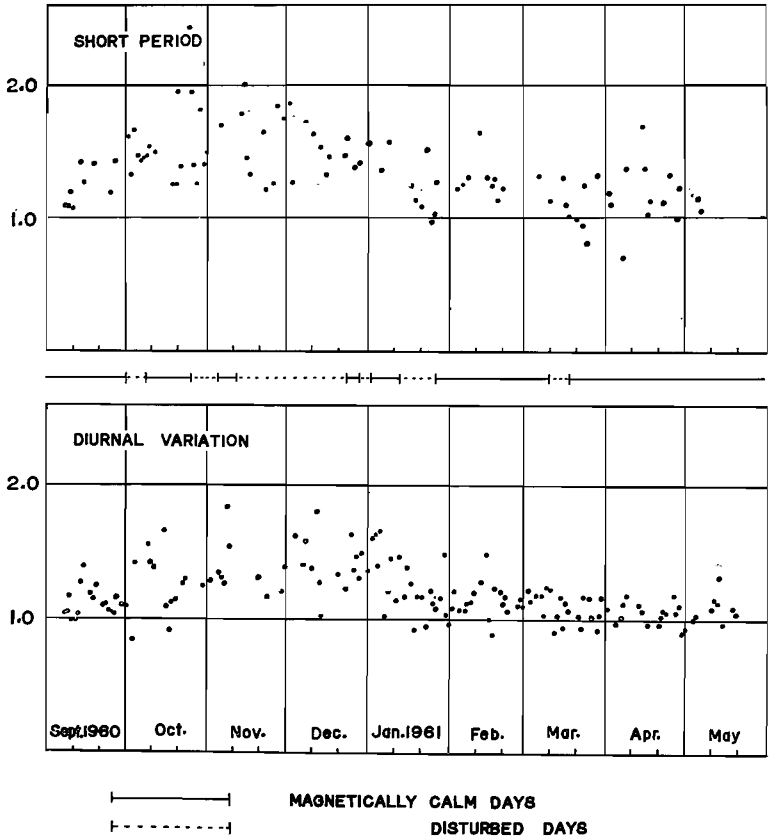

Fig. 5. Amplitude ratio of magnetic variation (Makimine/Oura).

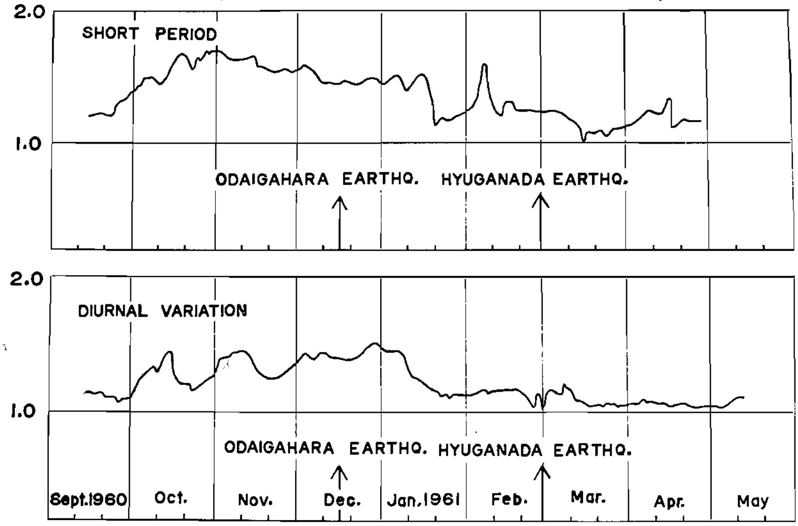

Fig. 6. Averaged amplitude ratio of magnetic variation (Makimine/Oura).

type, effect of Dellinger, initial part of a sudden-commencement of magnetic storm and the like. And after examination of the relation between the values of ratio of amplitude of short periods and their period (a half of the periods being from 2 minutes to 2 hours) or their amplitude themselves, it was ascertained that there were no definite effect upon the value of ratio by their period or amplitude. Consequently these changes of various period were altogether treated in the title of amplitude ratio of short period variation. The daily ratios of amplitude of diurnal variation and short period variation were listed in Table 2 and Fig. 3 and Fig. 4. As seen in Fig. 4 which showed a running mean of 15 days of daily value of amplitude ratio, the value of ratio did not show any noticeable change referring to the occurrence of Yoshino Earthquake of July 18, 1952. Contrary to the case of Yoshino Earthquake, the anomalous change of amplitude ratios were observed, referring to Table 3, Fig. 5 and 6, in a 15-day running mean curve of amplitude ratio of Makimine to that of Oura referring to two destructive earthquakes of Odaigahara (December 26, 1960, M=7.0, h=60 km, 75 km distant in E from Oura) and Hyuganada (already referred) near Makimine. To detail, the amplitude ratio commenced to show a high value of 1.2, 3 months before the occurrence of Odaigahara Earthquake and reached 1.5 in case of its occurrence as seen in Fig. 6. After that earthquake the value of ratio decreased gradually to 1.1 in nearly one month. Next, in case of Hyuganada Earthquake of epicenter near Makimine, the amplitude ratio began to decrease on Feb. 19 (the ratio being 1.16) and reached 1.0 on the day of earthquake. After that it recovered its initial, or normal value, in 10 days after the earthquake.

The daily geomagnetic variation contains two parts of direct and indirect effects. Namely, the direct part is derived from the dynamo effect (if the dynamo theory be adopted) through the ionosphere, and the indirect part, an induced one through the earth crust by the direct effect, and their ratio of effect is roughly estimated to be 2 : 1. From these circumstances, the variation of electric conductivity of the earth crust with time, if existing, would affect on a value of amplitude of daily variation. Consequently, if any suitable process of treatment to eliminate the time variation of direct effect were available, the time variation of amplitude of geomagnetic element observed at any one point would be interpreted to directly be connected with the time variation of the physical property of the crustal matter. This method would, in near future, be available to investigate the behavior of crustal matter and, consequently, the earthquake-forcasting.

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