

54. *On the Diurnal Periodicity of Felt Earthquakes.*

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It has been known that felt earthquakes, as a rule, is frequent at night.¹⁾ The writer inquired also into the time distribution of felt earthquakes at Tôkyô during twelve years since 1924, and obtained the similar result as before. Then he investigated statistically whether men are more sensitive to earthquake motions at night or in the day-time.

Diurnal Frequency Variation of Felt Earthquakes at Tôkyô.

The statistical investigation of earthquakes observed at Tôkyô has been carried out by F. Omori²⁾ in 1900. In his paper 2208 earthquakes were included, or on an average 92 in a year. But observation in the twelve years analysed hereafter comprises 64 earthquakes as the average number of only near earthquakes which were felt, and in addition 481 unfelt earthquakes and 81 distant earthquakes were recorded at the Seismological Institute in a year on an average. Such a great difference between old and new data might be due to the progress of seismometry during about twenty years.

The data used here are given in the Seismometrical Reports of the Earthquake Research Institute. The earthquakes in the reports were felt by several staffs of the above institute or the Seismological Institute who reside in Tôkyô, and their epicentres were within the radius of 160 km from Tôkyô. As regard to the harmonic analysis of the frequency distribution of felt earthquakes, the first harmonic of the diurnal variation has been noticed in the previous investigations. Then the writer looked upon only the first harmonic.

The results of the harmonic analysis in 1924~1935 are shown in Table I.

1) See for instance, B. GUTENBERG, *Handb. d. Geophys.* Bd. 4, § 277.

2) F. OMORI, *Rep. Imp. Earthq. Inv. Comm.*, 33 (1900), 30~116, and *Publ. Imp. Earthq. Inv. Comm.*, 8 (1902), 1~94.

Table I.

Year	Total number	Mean no. a_0	a_1/a_0	b_1/a_0	c_1	ϵ	α_1
1924	60	2.50	+ .196	+ .122	.229	.229	2 ^h 02 ^m
25	34	1.42	— .128	+ .069	.145	.304	10 07
26	68	2.83	+ .157	+ .251	.296	.215	3 52
27	65	2.71	+ .207	+ .227	.306	.220	3 02
28	78	3.25	+ .244	— .010	.244	.201	23 51
29	50	2.08	+ .566	+ .156	.605	.251	1 01
30	58	2.42	+ .249	+ .145	.288	.233	2 01
31	89	3.71	+ .139	+ .015	.140	.188	0 25
32	59	2.46	+ .262	— .134	.294	.231	22 11
33	63	2.62	+ .285	+ .053	.290	.224	0 42
34	64	2.66	— .250	— .116	.275	.221	13 39
35	78	3.25	+ .383	+ .007	.383	.201	0 04
(mean)			+ .193	+ .066			1 15

Comparing the amplitude c_1 of each year with the corresponding expectancy ϵ , it may be deduced from the theory of the periodogram analysis that the frequency distribution might depend on chance, for corresponding values of c and ϵ are nearly equal. But phase angles α_1 are mostly maximum at night. Then the theory of random walk was applied again on the above data. The theory has been used by Prof. T. Matuzawa³⁾ in a paper in this bulletin on the earthquake on March 2, 1933, so the explanation of it is omitted here. Applying the theory the expectancy for the average vector c was obtained as 0.09, and the amplitude of the average vector c_m as 0.217. Therefore c_m/c is equals to 2.42, and the probability that the average amplitude becomes greater than the above value is only 0.003. And the maximum of c_m is at about

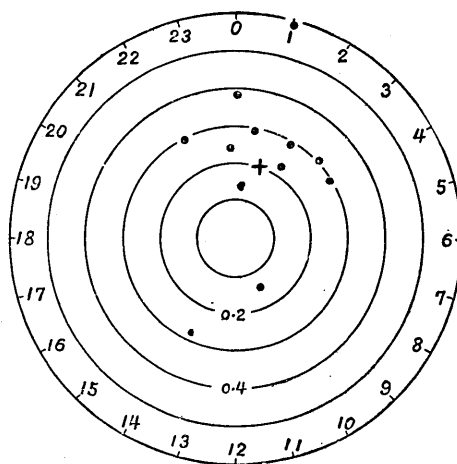


Fig. 1. Harmoine dial.

Cross indicates the average vector.

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3) T. MATUZAWA, *Bull. Earthq. Res. Inst.*, 14 (1936), 38~67.

1 h 15 m. Then it might be not accidental that the felt earthquakes occurred mostly at night at Tôkyô.

Two alternative interpretations may be put on the frequency distribution of felt earthquakes before mentioned. As F. de Montessus de Ballore⁴⁾ described, at night men are in repose and surroundings are silent, so men are sensitive to earthquake motions. Nextly if the frequency of moderate earthquakes be greater at night than in the daytime, the above mentioned Ballore's hypothesis may become wrong. But ascertaining of the latter consideration is difficult at present, for the times of occurrence of small earthquakes are hardly obtainable. Then according to the former interpretation the writer investigated the diurnal variation of the proportions of felt earthquakes to that of the total ones.

Diurnal Variation of Frequency-ratio of Felt Earthquakes to Total Ones observed with Seismographs.

Suitable data for the investigation were difficult to be obtained, and a few were available.

i) Late E. Makino who was an instructor of the Itô Primary School registered the time of felt earthquakes during swarm earthquakes took place at Itô, Idu Province, in 1930. He was so enthusiastic in the observation of the earthquakes that he hardly slept while the frequency of the earthquakes was great, as he might not fail in feeling an earthquake. His records from Feb. 20 to March 24 was used by the writer, which includes 1835 earthquakes. The frequency of the earthquakes at Itô was compared with that of the earthquakes registered at Misaki with an Omori portable seismograph ($V=120$ and $T=4$ sec). The total number of the earthquakes observed

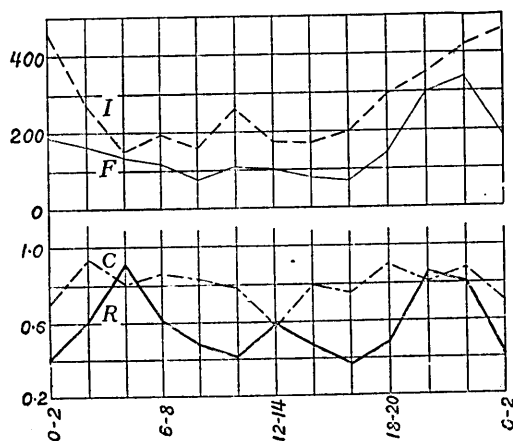


Fig. 2.

I=Number of earthquakes observed at Misaki in 2 hours,
 F=Number of felt earthquakes at Itô,
 R=Ratio (F/I),
 C=Correlation coefficient of I and F.

4) F. Montessus de BALLORE, *Arch. d. sciences phys. nat. Genf.*, 22 (1839).

at Misaki during the same interval was 3109. Supposing that the number of felt earthquakes is independent to that of the total earthquakes observed with seismographs, ratios of the two quantities were calculated, and the time variation of the ratios was investigated. The ratio and

Table II.

Hour	0~2	2~4	4~6	6~8	8~10	10~12	12~14	14~16	16~18	18~20	20~22	22~0	Sum
No. of earthq. felt at Itô	190	167	135	118	77	107	102	79	72	144	302	339	1832
No. of earthq. obs. at Misaki	460	275	152	193	160	263	174	170	198	294	349	421	3109
Ratio	.41	.61	.91	.61	.48	.41	.59	.47	.36	.49	.87	.80	
Correl. coeff.	.71	.95	.81	.87	.83	.79	.57	.80	.76	.91	.81	.87	

frequency of earthquakes in every two hours are shown in Table II and in Fig. 2. The number of the ratios, or number of pairs of felt and total earthquakes, obtained was as many as 278, then in addition correlation coefficients of felt and total earthquakes were calculated. The variations with respect to time of both ratios and correlation coefficients probably indicate that the felt earthquakes are more at night than in the day-time.

ii) Nextly the writer looked for other seismometrical reports which include considerably many felt earthquakes, for if the data

include a little felt earthquakes time variation of sensibility of men to the earthquake motions will not be found but frequency variation of moderate earthquakes will be shown. For the present purpose, the seismometrical reports of the Mito Meteorological Station in 1929 and Jan.~July, 1931 were used. The distribution of the frequency-ratios is shown in Table III and Fig. 3. The epoch of maximum sensitivity was obtained as at about 1h 20 m.

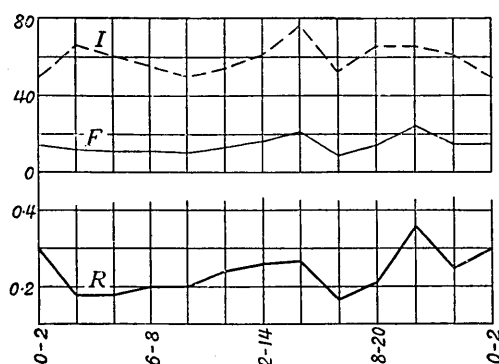


Fig. 3.

I=Number of earthquakes observed at Mito.

F=Number of earthquakes felt at Mito.

R=Ratio (F/I)

Table III.

Hour	0~2	2~4	4~6	6~8	8~10	10~12	12~14	14~16	16~18	18~20	20~22	22~0	Sum
No. of felt earthq.	15	12	11	11	10	13	16	21	9	14	24	15	170
No. of total earthq.	50	67	61	55	50	54	61	77	53	66	66	61	722
Ratio	.30	.18	.18	.20	.20	.24	.26	.27	.17	.21	.36	.25	

iii) The hourly numbers of fore-shocks and after-shocks of the Idu earthquake on Nov. 26, 1930 are given in the *Kensin-Zihô* 5 (1931), 136 ~ 137 by S. Sagisaka. The frequency ratios of earthquakes were obtained as before and are shown in Table IV and Fig. 4. Though the values of the ratios are small and the variation is not distinct, the distribution is different from the above two cases. The felt earthquakes were little at 0 ~ 3 h in this case. This result might be natural, for these earthquakes were intense merely in a small area, and at some distance although the seismographs recorded them men could hardly feel the motion of earthquakes.

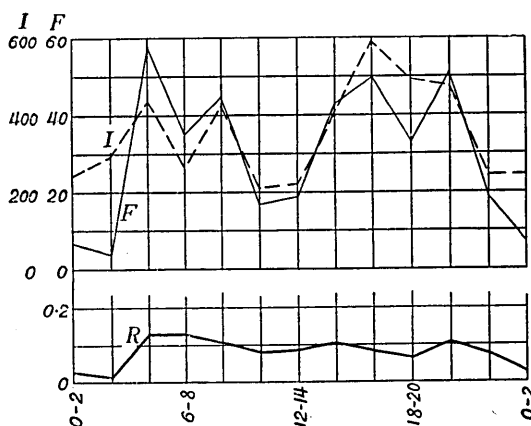


Fig. 4.

I=Number of earthquake observed with seismographs.

F=Number of felt earthquake.

R=Ratio (F/I).

Table IV.

Hour	0~2	2~4	4~6	6~8	8~10	10~12	12~14	14~16	16~18	18~20	20~22	22~0	Sum
No. of felt earthq.	7	4	58	35	45	17	19	43	50	33	51	19	381
No. of total earthq.	246	295	440	266	424	210	220	414	590	495	477	245	4322
Ratio	.03	.01	.13	.13	.11	.08	.09	.10	.09	.07	.11	.08	

Conclusion.

From the above investigations, the writer arrived at a conclusion that men are more sensitive to feel earthquake motions at night than in the day time. The result may be interpreted as Ballore wrote, or in another way as follows: moderate earthquakes are frequent at night, consequently men feel more earthquakes at night. But the latter consideration is not proved now, so in statistics of earthquake frequency the influence of the intensity of the earthquakes may be worthy of caution.

54. 有感地震の1日中の分布に就いて

地震學教室 岸 上 冬 彦

地震研究所の地震観測報告を用ひて大正 14 年から昭和 10 年まで 12 年間の東京に於ける有感地震の1日中の分布を統計理論によつて調べた。其の結果有感地震は午前 1 時頃に最も多かつたことが判つた。次に此の事は人が夜に地震動を感じ易い爲であるか否かを調べて見た。即ち昭和 5 年の伊東地震、水戸測候所観測の地震、昭和 5 年の伊豆地震の前震餘震等について、有感地震と地震計観測による地震總數との比をさつて、その比の1日中の變化を見るに夜間地震を感じ易い様に見えるが、又地震の強さが感覺に影響することもある様である。其故地震計観測結果について統計するには各地震の強さを考慮に入れる必要があらう。
