

THE SAKURA-JIMA ERUPTIONS AND EARTHQUAKES. V.

Seismographical Observations of the Fore-shocks, After-shocks,
and After-outbursts of the Great Sakura-jima Eruption of 1914.

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With Plates LXXVII—LXXXVII.

CHAPTER I. OBSERVATION OF THE FORE-SHOCKS AT THE KAGOSHIMA METEOROLOGICAL OBSERVATORY.

1. *Gray-Milne seismograph observation at Kagoshima.*

The Gray-Milne seismograph observation made on Jan. 11th and 12th, 1914, at the meteorological observatory of Kagoshima* forms a valuable contribution to the knowledge of the fore-shocks of the great Sakura-jima eruption which began on the 12th, at 10 A.M. The instrument, at rest in ordinary times, registered only those shocks which were intense enough to affect the electric contact-maker and thereby start the recording-drum into motion; the pointer magnification being 5 for the E.W. and the N.S. components and 10 for the vertical component. As will be seen from the list in Table I, the fore-shocks observed at Kagoshima numbered 418 in the course of the first $30\frac{1}{3}$ hours between 3.41.20 A.M., on the 11th,

* See the Bulletin, Vol. VIII, No. 1.

TABLE I. HOURLY FREQUENCY OF THE EARTHQUAKES OBSERVED AT KAGOSHIMA ON JAN. 11TH AND 12TH, 1914, CLASSIFIED ACCORDING TO THE INTENSITY OF MOTION.

Day. Hour.	11th.						12th.					
	Unfelt.	Sensible.					Unfelt.	Sensible.				
		Slight.	Mode-rate.	Strong.	Violent.	Sum.		Slight.	Mode-rate.	Strong.	Violent.	Sum.
0-1 A.M.							4	16	1	—	—	17
1-2							2	7	—	—	—	7
2-3							3	4	—	—	—	4
3-4	2	1	—	—	—	1	14	12	1	—	—	13
4-5	5	1	2	—	—	3	5	6	2	—	—	8
5-6	2	2	1	—	—	3	8	11	1	—	—	12
6-7	—	—	—	—	—	—	3	15	3	—	—	18
7-8	1	1	—	—	—	1	1	11	1	—	—	12
8-9	5	2	—	—	—	2	12	12	1	—	—	13
9-10	3	1	—	1	—	2	17	7	—	—	—	7
10-11	3	—	—	—	—	—	13	4	—	—	—	4
11-12	4	5	1	—	—	6	7	4	—	—	—	4
0-1 P.M.	6	1	1	1	—	3	5	1	—	—	—	1
1-2	10	1	1	—	—	2	3	—	—	—	—	—
2-3	8	5	1	—	—	6	5	—	—	—	—	—
3-4	10	3	1	—	—	4	2	—	—	—	—	—
4-5	14	1	1	—	—	2	2	—	—	—	—	—
5-6	10	4	1	—	—	5	2	—	—	—	—	—
6-7	3	5	2	—	—	7	—	—	—	—	1	1
7-8	4	3	5	—	—	8						
8-9	15	10	3	—	—	13						
9-10	5	10	4	—	—	14						
10-11	12	11	3	—	—	14						
11-12	5	15	—	—	—	15						
Sum.	127	82	27	2	—	111	108	110	10	—	1	121

and 10 A.M., on the 12th. Thereafter, with the commencement of the eruption, the frequency rapidly decreased, but the disturbances continued to occur more or less for the several subsequent days. In Table II the list extends to the 18th of January (1914), bringing the seismic number up to 505. Had a tromometer been in use in Kagoshima at the commencement of the eruption, the earthquakes registered, both sensible and unfelt, would of course have been considerably more numerous.

The Kagoshima meteorological observatory stood on the top of a flat hill, 120 m. above sea-level, outside the northern end of the city, at $\varphi=31^{\circ} 36' N.$, $\lambda=130^{\circ} 33' E.$ * Its site was at the distance of 10.4 km. from the centre of the Minami-dake crater in Sakura-jima, and was nearly in the accurate prolongation of the N. $73^{\circ} W.$ -S. $73^{\circ} E.$ eruption zone connecting the series of the craterlets on the S.E. and the W. flanks of the mountain. I give next a few remarks on the time relation of the fore-shocks.

2. Frequency distribution of the fore-shocks. According to Table I, the intensity distribution of the 467 shocks observed between 3 A.M., on the 11th, and 7 P.M., on the 12th, was as follows:—

Earthquake Intensity.	Number of Earthquakes.
(i) Unfelt,	235
(ii) Slight,	192
(iii) Moderate,	37
(iv) Strong,	2
(v) Violent (semi-destructive),	1

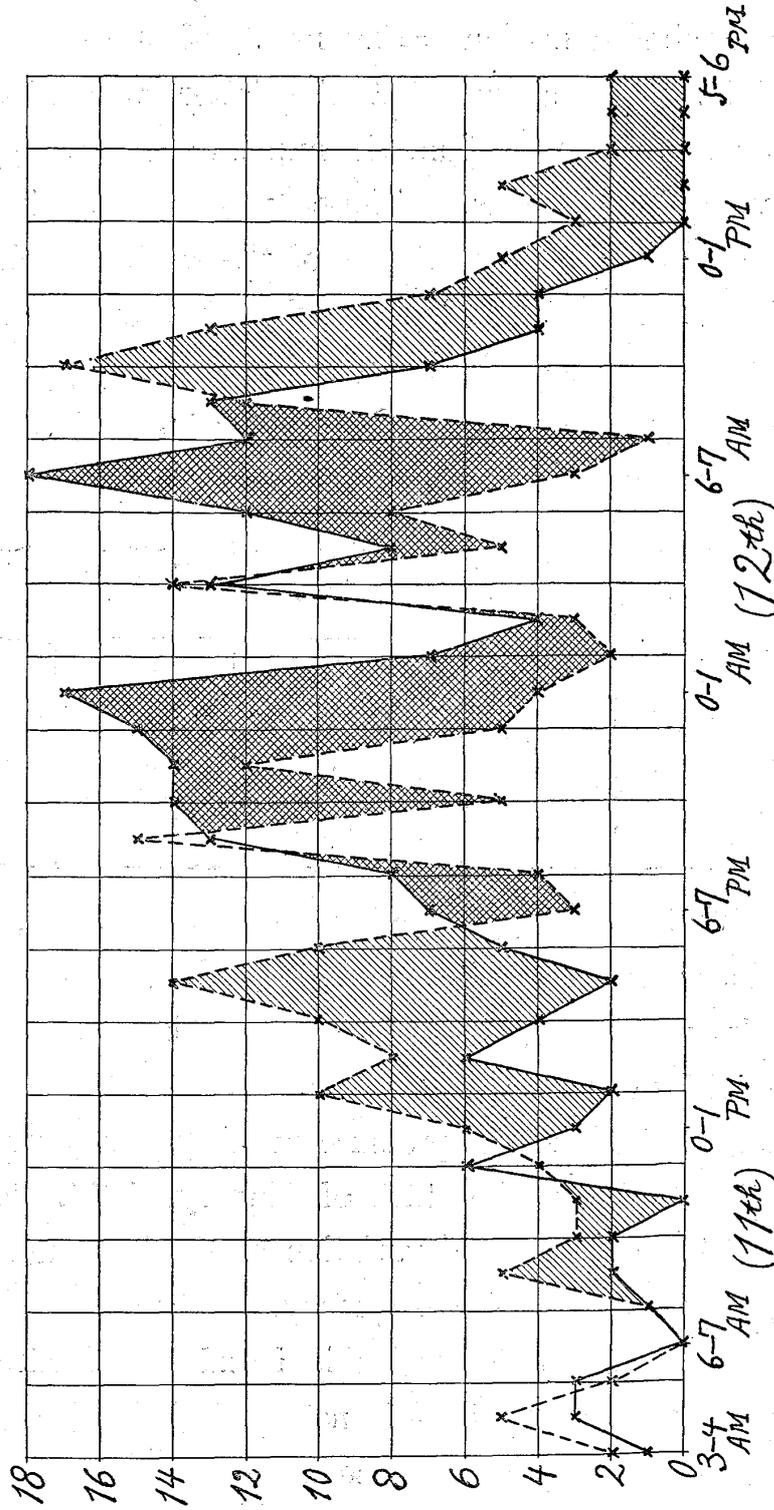
Thus the frequency of the (i) unfelt earthquakes was exactly 50% and those of the sensible (ii) slight and (iii) moderate shocks respectively 41 and 8% of the total number. The (iii) moderate

* Removed in 1915 to its present position on the low suburb ground to the south of the city, at $\varphi=31^{\circ} 34' N.$, $\lambda=130^{\circ} 33' E.$

earthquakes attained the maximum frequency between 6 and 11 P.M., on the 11th; while the two strong earthquakes took place between 9 and 10 A.M., and between 0 and 1 P.M., on the 11th. In other words, the (iii) and (iv) shocks occurred or were most numerous respectively about 24 and 12 hours before the first commencement of the eruption at 10 A.M., on the 12th.

As will seen from fig. 1, the course of the time variation of the frequency of the unfelt earthquakes was different in several points from that of the sensible on s. Amongst the others, during the 1st 15 hours, i.e., from 3 A.M. till 6 P.M., on the 11th, the hourly number of the unfelt earthquakes remained on the whole greater than that of the others, in the ratio of 83 to 40, or nearly 2:1; while, during the next 15 hours, between 6 P.M., on the 11th, and 9 A.M., on the 12th, the sensible earthquakes became more numerous than the unfelt, in the ratio of 175:96, or nearly 2:1. This latter phenomenon, or the frequency preponderance of the stronger earthquakes over the smaller ones, is highly peculiar, and probably implies the intensification of the individual seismic movements in the hours immediately preceding the eruption, a supposition which is in accordance with the nature of the volcanic disturbances consisting of an abundant emission of smokes and ashes and an outflow of lava. From about 9 or 10 A.M., on the 12th, at the time of commencement of the outbursts, the unfelt earthquakes became again more numerous than the sensible ones, both sorts of the shakings quickly decreasing till the time of occurrence of the violent shock at 6½ P.M. on the same day. Again, none of the premonitory earthquakes, which may be supposed to have been brought practically to end at about 3 or 4 P.M., on the 12th, was destructive or semi-destructive, and their maximum E.W. component motion (2a) was, according to the tromometer record in

Fig. 1. Hourly Frequency Variation of the Sakura-jima Fore-shocks instrumentally registered at the Kagoshima Meteorological Observatory.



▨....Unfelt. ▨....Sensible.

Dotted line relates to the unfelt earthquakes.

Full line " " sensible "

Tokyo, less than 0.03 mm., being considerably smaller than the corresponding maximum motion (=2.9 mm.) of the strong shock above referred to. This shows that the latter was of a great magnitude altogether different from the numerous precursory shakings of the volcanic outbursts. These two facts relating to the time of occurrence and the magnitude of the strong shock in the evening of the 12th seem to indicate that it was in nature a large earthquake and not local to the Sakura-jima only.

3. 3-hourly frequency of the fore-shocks. The 3-hourly frequency of the premonitory earthquakes was as follows:—

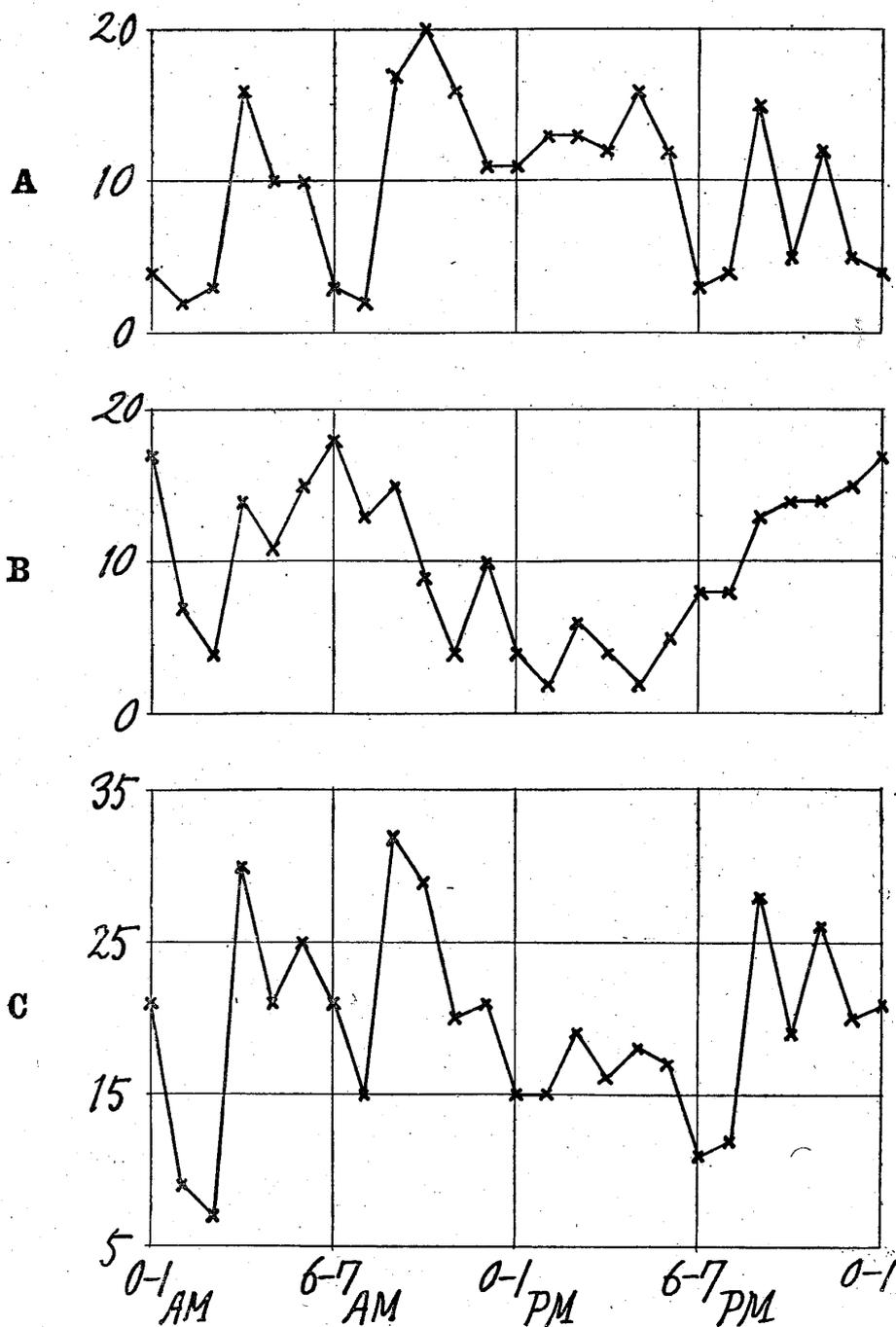
Hour.	11th.	12th.	Hour.	11th.	12th.
0-3 A.M.	0	37	0-3 P.M.	35	14
3-6	16	60	3-6	45	6
6-9	9	59	6-9	50	2
9-12	18	52	9-12	65	

It will be seen that the frequency increase during the 11th was in a nearly linear relation to the time, with the mean rate of about 3.0 shocks per hour.

In Table XIV of the Bulletin, Vol. VIII, No. 2, is given the hourly value of the barometric pressure at Kagoshima during the 5 days, from the 10th to the 14th of January, 1914. There is no apparent relation between the variation of the barometric pressure and that of the earthquake frequency.

4. Diurnal variation. From Table I and the illustration in fig. 2, it will be seen that the diurnal variation of the unfelt earthquakes indicates the minimum hourly frequency at 6-8 A.M. and 6-8 P.M., and also at 1-2 A.M. and 1-2 P.M., being rather opposite to that of the sensible shocks. The frequency variation of

Fig. 2. Diurnal Frequency Variation of the Sakura-jima Fore-shocks instrumentally registered at the Kagoshima Meteorological Observatory.



(A) Unfelt Earthquakes. (B) Sensible Earthquakes.
 (C) Unfelt and Sensible Earthquakes taken together.

the unfelt and sensible earthquakes taken together shows 4 maxima more or less distinctly, at 8–9 A.M. and P.M., and at 3–4 A.M. and P.M. The diurnal frequency variation of the Sakura-jima fore-shocks may thus be considered as having been maximum at the hours of the barometric maximum and minimum: a result similar to the relation found of the ordinary earthquakes in Tokyo, and of the *jinari* (earth sounds) at the hot spring place of Arima.

TABLE II. LIST OF THE VOLCANIC EARTHQUAKES REGISTERED WITH A GRAY-MILNE SEISMOGRAPH AT THE METEOROLOGICAL OBSERVATORY OF KAGOSHIMA. JAN., 11TH TO 18TH, 1914.

No.	Time of Occurrence.	Intensity.	Nature of motion.*	No.	Time of Occurrence.	Intensity.	Nature of motion.*
Jan. 11th, 1914.				Jan. 11th 1914.			
1	3 41 20 A.M.	0		14	5 07 40 A.M.	0	
2	43 00	0		15	27 45	1	Quick.
3	59 00	1	Quick.	16	58 00	2	{ Quick, with vert. motion; houses shaken.
4	4 01 40	2	{ Quick, with vert. vibrations.	17	7 45 44	1	Quick.
5	04 00	0		18	59 00	0	
6	06 20	0		19	8 01 00	0	
7	08 20	0		20	13 00	0	
8	15 15	1	Quick.	21	23 00	1	Quick.
9	26 40	2	{ Quick, with vert. vibrations; houses shaken.	22	29 00	0	
10	45 40	0		23	30 40	0	
11	54 00	0		24	39 00	0	
12	5 03 00	1	Quick.	25	56 00	1	Quick.
13	07 15	0		26	9 02 00	1	Do.

* The intensity of earthquake motion is distinguished as *unfelt*, *slight*, *rather moderate*, *moderate*, *rather strong*, *strong*, and *violent*. These seven degrees are denoted in this table respectively by the numerals 0, 1, 2, 3, 4, 5, and 6:—

0, Unfelt; 1, Slight; 2, Rather Moderate.; 3, Moderate; 4, Rather Strong; 5, Strong; 6, Violent.

No.	Time of Occurrence.	Intensity.	Nature of motion.	No.	Time of Occurrence.	Intensity.	Nature of motion.
Jan. 11th, 1914.				Jan. 11th, 1914.			
27	^h 9 ^m 07 ^s 00 A.M.	0		56	^h 1 ^m 24 ^s 00 P.M.	3	{ Quick, with vert. motion; houses shaken.
28	21 00	0		57	29 00	0	
29	36 00	0		58	41 30	0	
30	57 45	5	{ Quick, with vert. motion; pendulumn clocks stopped.	59	45 00	0	
31	10 37 30	0		60	46 20	0	
32	45 33	0		61	50 00	0	
33	58 00	0		62	51 25	1	Quick.
34	11 10 20	0		63	53 00	0	
35	12 30	1	Quick.	64	54 00	0	
36	28 00	1	Do.	65	2 01 00	0	
37	30 00	0		66	02 30	0	
38	32 00	1	Quick.	67	05 00	1	Quick.
39	33 40	0		68	07 30	0	
40	38 25	1	Quick.	69	09 40	1	Quick.
41	42 00	1	Do.	70	15 00	0	
42	45 00	0		71	17 00	0	
43	46 54	2	{ Quick, with vert. motion; houses shaken.	72	23 00	1	Quick.
44	0 05 00 P.M.	1	Quick.	73	30 10	0	
45	09 30	0		74	34 17	1	Quick.
46	27 11	3	{ Strong vert. motion, with earth sound; ground cracked.	75	36 25	0	
47	31 17	0		76	45 23	1	Quick.
48	34 00	0		77	54 00	0	
49	43 00	5	{ Quick, with vert. motion; pendulumn clocks stopped.	78	54 50	2	{ Quick, with vert. vibration.
50	47 10	0		79	3 01 00	1	Quick.
51	50 00	0		80	09 20	0	
52	54 00	0		81	14 20	0	
53	1 04 35	0		82	15 50	0	
54	19 00	0		83	18 00	1	Quick.
55	23 49	0		84	30 40	0	

No.	Time of Occurrence.	Inten- sity.	Nature of motion.	No.	Time of Occurrence.	Inten- sity.	Nature of motion.
Jan. 11th, 1914.				Jan. 11th, 1914.			
85	^h 3 ^m 34 ^s 00 P.M.	0		114	^h 5 ^m 20 ^s 00 P.M.	0	
86	36 40	0		115	21 00	0	
87	39 00	0		116	24 00	3	{ Quick, with vert. mo- tion; houses shaken.
88	46 34	0		117	27 00	0	
89	50 00	0		118	43 00	0	
90	51 30	1	Quick.	119	44 55	1	Quick.
91	52 10	2	{ Quick, with vert. mo- tion; houses shaken.	120	50 00	0	
92	58 00	0		121	51 00	0	
93	4 01 20	0		122	58 00	1	Quick.
94	07 00	0		123	59 00	1	Do.
95	12 10	2	{ Quick, with vert. mo- tion; houses shaken.	124	6 01 00	1	Do.
96	14 00	0		125	01 30	1	Do.
97	17 25	0		126	14 20	0	
98	20 00	0		127	15 40	0	
99	23 00	0		128	20 00	0	
100	27 00	0		129	22 00	1	Quick.
101	35 00	0		130	24 00	1	Do.
102	38 00	0		131	25 00	1	Do.
103	42 00	0		132	47 00	2	{ Quick, with vert. mo- tion; houses shaken.
104	43 20	0		133	53 00	2	Do.
105	47 00	0		134	7 01 00	2	Do.
106	48 29	1	Quick.	135	10 00	1	Quick.
107	56 20	0		136	15 15	1	Do.
108	58 00	0		137	22 10	2	{ Quick, with vert. mo- tion; houses shaken.
109	5 02 30	0		138	30 20	2	Do.
110	04 00	1	Quick.	139	34 00	0	
111	05 30	0		140	36 00	1	Quick.
112	11 30	0		141	42 00	2	{ Quick, with vert. mo- tion; houses shaken.
113	15 30	0		142	47 00	0	

No.	Time of Occurrence.	Intensity.	Nature of motion.	No.	Time of Occurrence.	Intensity.	Nature of motion.
Jan. 11th, 1914.				Jan. 11th, 1914.			
143	^h 7 ^m 51 ^s 00 P.M.	3	{ Quick, with vert. motion; houses shaken.	172	^h 8 ^m 57 ^s 00 P.M.	1	Quick.
144	53 00	0		173	58 00	1	<i>Do.</i>
145	58 00	0		174	9 00 00	2	{ Quick, with vert. motion; houses shaken.
146	8 00 00	1	Quick.	175	07 00	1	Quick.
147	05 00	0		176	08 00	2	{ Quick, with vert. motion; houses shaken.
148	08 00	0		177	12 00	1	Quick.
149	11 30	0		178	18 00	0	
150	12 00	2	{ Quick, with vert. motion; houses shaken.	179	23 00	1	Quick.
151	13 00	1	Quick.	180	28 00	1	<i>Do.</i>
152	18 00	0		181	30 00	1	<i>Do.</i>
153	19 00	0		182	33 00	0	
154	21 00	0		183	37 00	1	Quick.
155	23 00	2	{ Quick, with vert. motion; houses shaken.	184	38 00	0	
156	26 00	1	Quick.	185	39 00	1	Quick.
157	28 00	0		186	44 00	0	
158	32 00	0		187	45 00	1	Quick.
159	34 00	2	{ Quick, with vert. motion; houses shaken.	188	46 00	1	<i>Do.</i>
160	41 00	0		189	48 00	0	
161	43 00	0		190	49 00	1	Quick.
162	44 00	0		191	52 00	2	{ Quick, with vert. motion; houses shaken.
163	44 30	0		192	59 00	2	<i>Do.</i>
164	45 00	1	Quick.	193	10 00 00	2	<i>Do.</i>
165	46 00	1	<i>Do.</i>	194	01 00	0	
166	48 00	0		195	03 00	1	Quick.
167	48 30	0		196	04 00	1	<i>Do.</i>
168	49 00	1	Quick.	197	07 00	1	<i>Do.</i>
169	51 00	1	<i>Do.</i>	198	11 00	1	<i>Do.</i>
170	55 00	0		199	13 00	0	
171	56 00	1	Quick.	200	16 00	0	

No.	Time of Occurrence.	Intensity.	Nature of motion.	No.	Time of Occurrence.	Intensity.	Nature of motion.
Jan. 11th, 1914.				Jan. 11th, 1914.			
201	^h 10 ^m 17 ^s 00 P.M.	0		230	^h 11 ^m 28 ^s 00 P.M.	0	
202	9 00	1	Quick.	231	29 00	1	Quick.
203	21 00	1	<i>Do.</i>	232	30 00	1	<i>Do.</i>
204	22 00	0		233	34 00	0	
205	24 00	2	{ Quick, with vert. motion; houses shaken.	234	35 00	1	Quick.
206	27 00	0		235	37 00	1	<i>Do.</i>
207	30 00	0		236	51 00	1	<i>Do.</i>
208	31 00	1	Quick.	237	53 00	1	<i>Do.</i>
209	35 00	1	<i>Do.</i>	238	58 00	1	<i>Do.</i>
210	38 00	1	<i>Do.</i>	Jan. 12th, 1914.			
211	39 00	1	<i>Do.</i>	239	0 03 00 A.M.	1	Quick.
212	44 00	0		240	04 00	1	<i>Do.</i>
213	45 00	0		241	05 00	0	
214	47 00	0		242	06 00	1	Quick.
215	49 00	0		243	09 00	1	<i>Do.</i>
216	50 00	0		244	14 00	0	
217	51 00	1	Quick.	245	18 00	1	Quick.
218	58 00	3	{ Quick, with vert. motion; houses shaken.	246	22 00	1	<i>Do.</i>
219	11 03 00	1	Quick.	247	24 00	1	<i>Do.</i>
220	09 00	1	<i>Do.</i>	248	25 00	1	<i>Do.</i>
221	11 00	0		249	32 00	1	<i>Do.</i>
222	14 00	1	Quick.	250	33 00	1	<i>Do.</i>
223	15 00	1	<i>Do.</i>	251	34 00	0	
224	17 00	0		252	35 00	1	Quick.
225	19 00	1	Quick.	253	40 00	3	{ Quick, with vert. motion; houses shaken.
226	20 00	1	<i>Do.</i>	254	41 00	1	Quick.
227	20 30	1	<i>Do.</i>	255	51 00	1	<i>Do.</i>
228	23 00	0		256	52 00	1	<i>Do.</i>
229	24 30	1	Quick.				

No.	Time of Occurrence.	Intensity.	Nature of motion.	No.	Time of Occurrence.	Intensity.	Nature of motion.
Jan. 12th, 1914.				Jan. 12th, 1914.			
257	0 ^h 54 ^m 00 ^s A.M.	0		285	3 ^h 29 ^m 00 ^s A.M.	1	Quick.
258	55 00	1	Quick.	286	32 00	0	
259	57 00	1	<i>Do.</i>	287	35 00	2	{ Quick, with vert. motion; houses shaken.
260	1 00 00	0		288	36 00	1	Quick.
261	06 00	0		289	38 00	1	<i>Do.</i>
262	08 00	1	Quick.	290	40 00	0	
263	20 00	1	<i>Do.</i>	291	41 00	0	
264	26 00	1	<i>Do.</i>	292	43 00	1	Quick.
265	31 00	1	<i>Do.</i>	293	44 00	0	
266	43 00	1	<i>Do.</i>	294	46 00	0	
267	51 00	1	<i>Do.</i>	295	47 00	0	
268	54 00	1	<i>Do.</i>	296	48 00	0	
269	2 05 00	1	<i>Do.</i>	297	50 00	1	Quick.
270	09 00	1	<i>Do.</i>	298	54 00	0	
271	20 00	0		299	56 00	0	
272	29 00	0		300	57 00	0	
273	41 00	1	Quick.	301	58 00	0	
274	49 00	1	<i>Do.</i>	302	59 00	0	
275	54 00	0		303	4 04 00	1	Quick.
276	3 04 00	1	Quick.	304	06 00	0	
277	11 00	1	<i>Do.</i>	305	08 00	2	{ Quick, with vert. motion; houses shaken.
278	14 00	1	<i>Do.</i>	306	09 00	1	Quick.
279	16 00	1	<i>Do.</i>	307	10 00	0	
280	18 00	1	<i>Do.</i>	308	23 00	0	
281	20 00	1	<i>Do.</i>	309	30 00	1	Quick.
282	22 00	0		310	37 00	0	
283	23 00	1	Quick.	311	42 00	0	
284	27 00	0		312	43 00	2	{ Quick, with vert. motion; houses shaken.

No.	Time of Occurrence.	Intensity.	Nature of motion.	No.	Time of Occurrence.	Intensity.	Nature of motion.
Jan. 12th, 1914.				Jan. 12th, 1914.			
313	4 ^h 46 ^m 00 ^s A.M.	1	Quick.	341	6 ^h 15 ^m 30 ^s A.M.	2	Quick; houses shaken.
314	49 00	1	* <i>Do.</i>	342	25 00	1	Quick.
315	56 00	1	* <i>Do.</i>	343	26 00	1	<i>Do.</i>
316	5 05 00	1	* <i>Do.</i>	344	27 00	1	<i>Do.</i>
317	06 00	1	<i>Do.</i>	345	28 00	0	
318	07 00	0		346	32 00	2	Quick; houses shaken.
319	15 00	0		347	34 00	1	Quick.
320	16 00	1	Quick.	348	38 00	1	<i>Do.</i>
321	17 00	1	<i>Do.</i>	349	41 00	1	<i>Do.</i>
322	19 00	0		350	45 00	0	
323	21 00	0		351	47 00	0	
324	23 00	0		352	52 00	1	* Quick.
325	29 00	0		353	53 00	1	<i>Do.</i>
326	31 00	1	Quick.	354	55 00	1	<i>Do.</i>
327	33 00	1	<i>Do.</i>	355	57 00	1	<i>Do.</i>
328	35 00	1	<i>Do.</i>	356	59 00	1	<i>Do.</i>
329	38 00	0		357	7 03 00	1	<i>Do.</i>
330	41 00	1	Quick.	358	10 00	1	<i>Do.</i>
331	47 00	1	<i>Do.</i>	359	14 00	1	<i>Do.</i>
332	49 00	3	{ Quick, with vert motion; houses shaken.	360	17 00	1	* <i>Do.</i>
333	51 00	0		361	23 00	1	<i>Do.</i>
334	55 00	1	Quick.	362	25 00	1	<i>Do.</i>
335	57 00	1	<i>Do.</i>	363	32 00	1	<i>Do.</i>
336	6 01 00	1	<i>Do.</i>	364	33 00	0	
337	03 00	2	Slow; houses shaken.	365	34 00	1	* Quick.
338	06 00	1	Quick.	366	41 00	1	* Slow.
339	09 00	1	<i>Do.</i>	367	46 00	2	Quick; houses shaken.
340	11 00	1	<i>Do.</i>	368	47 00	1	* Quick.

* Not instrumentally registered.

No.	Time of Occurrence	Inten- sity.	Nature of motion.	No.	Time of Occurrence.	Inten- sity.	Nature of motion.
Jan. 12th, 1914.				Jan. 12th, 1914.			
369	^{h m s} 7 49 00 A.M.	1	Quick.	397	^{h m s} 9 08 00 A.M.	0	
370	8 05 00	1	<i>Do.</i>	398	10 00	0	
371	06 00	0		399	10 30	1	Quick.
372	07 00	1	Quick.	400	12 00	0	
373	09 00	1	<i>Do.</i>	401	13 00	1	Quick.
374	14 00	1	<i>Do.</i>	402	16 00	0	
375	16 00	0		403	17 00	1	Quick.
376	17 00	1	Quick.	404	20 00	0	
377	19 00	0		405	26 00	0	
378	23 00	0		406	27 30	1	Quick.
379	25 00	1	Quick.	407	30 00	0	
380	27 00	3	Quick; houses shaken.	408	32 00	0	
381	29 00	1	Quick.	409	34 00	0	
382	33 00	0		410	35 00	0	
383	35 00	0		411	37 00	1	Quick.
384	35 35	1	Quick.	412	44 00	0	
385	38 00	1	<i>Do.</i>	413	45 00	0	
386	39 00	1	<i>Do.</i>	414	48 00	0	
387	41 00	1	<i>Do.</i>	415	51 00	1	Quick.
388	44 00	0		416	53 00	1	<i>Do.</i>
389	46 00	0		417	55 00	0	
390	47 00	0		418	57 00	0	
391	51 00	0		419	10 01 00	0	
392	54 00	0		420	04 00	0	
393	55 00	1	Quick.	421	06 00	0	
394	58 00	0		422	07 00	0	
395	9 05 00	0		423	14 00	1	Quick.
396	07 00	0		424	16 30	1	<i>Do.</i>

No.	Time of Occurrence.	Intensity.	Nature of motion.	No.	Time of Occurrence.	Intensity.	Nature of motion.
Jan. 12th, 1914.				Jan. 12th, 1914.			
425	10 ^h 18 ^m 00 ^s A.M.	0		453	1 ^h 06 ^m 00 ^s P.M.	0	
426	21 30	1	Quick.	454	14 00	0	
427	23 00	0		455	28 20	0	
428	24 00	0		456	2 18 30	0	
429	32 00	0		457	22 00	0	
430	34 00	0		458	33 00	0	
431	44 30	0		459	37 00	0	
432	49 00	1	Quick.	460	43 00	0	
433	53 00	0		461	3 15 00	0	
434	56 00	0		462	40 00	0	
435	58 00	0		463	4 09 00	0	
436	11 00 00	0		464	28 00	0	
437	02 00	1	Quick.	465	5 06 00	0	
438	13 35	1	Do.	466	46 00	0	
439	15 00	0		467	6 29 00	6	烈震
440	23 00	1	Quick.	468	8 11 00	1	* Quick.
441	27 00	1	Do.	469	9 13 00	1	* Do.
442	32 00	0		Jan. 13th, 1914.			
443	34 00	0		470	9 36 00 A.M.	1	* Quick.
444	38 00	0		471	4 09 00 P.M.	4	* Quick; houses shaken.
445	42 00	0		472	11 00	1	* Quick.
446	43 00	0		473	45 00	1	* Do.
447	0 06 30 P.M.	1	Quick.	474	11 45 00	1	* Do.
448	08 00	0		Jan. 14th, 1914.			
449	17 00	0		475	0 34 00 A.M.	1	* Quick.
450	20 00	0		476	2 10 00	1	* Do.
451	34 00	0					
452	57 00	0					

* Not instrumentally registered.

No.	Time of Occurrence.	Inten- sity.	Nature of motion.	No.	Time of Occurrence.	Inten- sity.	Nature of motion.
Jan. 15th, 1914.				Jan. 16th, 1914.			
477	^h 1 ^m 42 ^s 00 P.M.	2	Quick; houses shaken.	493	^h 0 ^m 37 ^s 00 P.M.	0	
478	6 30 00	0		494	2 27 00	1	Quick.
479	50 00	0		495	6 04 00	0	
480	7 05 00	1	Quick.	496	20 00	0	
481	44 00	0		Jan. 17th, 1914.			
482	50 00	0		497	2 50 00 A.M.	1	Quick.
483	9 25 00	0		498	5 38 00	1	Do.
484	10 59 00	0		499	43 00	0	
485	11 43 00	0		Jan. 18th, 1914.			
Jan. 16th, 1914.				500	5 31 00 A.M.	1	× Quick.
486	4 50 00 A.M.	0		501	11 33 00	1	× Do.
487	5 10 00	0		502	1 10 00 P.M.	0	×
488	11 00	0		503	2 43 00	0	×
489	7 18 00	0		504	3 11 00	0	×
490	10 09 00	1	Quick.	505	6 57 00	2	{ × Quick; houses shaken.
491	11 57 00	0					
492	0 15 00 P.M.	0					

× Registered by a horizontal pendulum tromometer.

5. Time difference between the successive earthquake occurrences. The 471 earthquakes registered at the Kagoshima meteorological observatory from Jan. 11th, 3.41.20 A.M. to the next day, 9.13.00 P.M., had the average interval of 5^m18^s . Of these, 404 occurred at successive time differences less than 5 minutes, the maximum frequency, about 46% in amount, corresponding to the interval of about 2 minutes. (See Table III.)

If we take the series of 2 or more earthquakes with time

difference under 5 minutes as composing a group, and combine their average time of occurrence with those of single earthquakes, the maximum frequency corresponds to the intervals of 10 to 13 minutes. (See Tables IV and V.)

Comparison with the after-shocks of great tectonic earthquakes. For the sake of comparison I give in Tables III and V the relative frequency of the shocks corresponding to the different lengths of the successive interval for the cases of the after-shocks of the Mino-Owari, Nemro, and Akita earthquakes, as follows:—

Mino-Owari Eqke. of Oct. 28th, 1891, at 6.37 A.M.: 1258 after-shocks observed at the Gifu meteorological observatory between Oct. 29th and Nov. 10th, 1891.

Nemro Eqke. of March 22nd, 1894, at 7.56 P.M. : 276 after-shocks observed at the Nemro met. observatory between March 22nd (7.56.06 P.M.) and 25th (11.44.00 P.M.) 1894.

Riku-U Eqke. of Aug. 31st, 1896, at 5 P.M. : 88 after-shocks observed at the Akita met. observatory between Aug. 31st (5.51.54 P.M.) and Sept. 1st (2.53.42 P.M.), 1896.

The numbers of the shocks occurring at successive intervals less than 5 minutes were 681; 146; and 47 respectively for the Mino-Owari, Nemro, and Riku-U earthquakes; the maximum frequency at Gifu and Nemro, 31 to 49%, corresponding to the interval of about 2 minutes. The time interval in question must depend, of course, on the magnitude of the volcanic tension or seismic stress at the source of disturbance and the radial distance of the observing place from the latter. Still the quick successive occurrences of the volcanic earthquakes at Kagoshima and of the tectonic after-shocks at Gifu and Nemro, as will be seen from Table III and fig. 3, followed nearly similar courses, the frequency culminating in each case at the interval of about 2 min.,

TABLE III. PERCENTAGE AMOUNT OF THE NUMBER OF THE EARTHQUAKES OCCURRING AT DIFFERENT SUCCESSIVE INTERVALS.

Interval.	Kagoshima.	Gifu.	Nemro.	Akita.
$\frac{m}{s} - \frac{m}{s}$ 0.00—0.30	0.0%	0.4%	2.1%	—
0.30—1.30	12.5	18.7	14.9	—
1.30—2.30	47.7	30.6	49.0	—
2.30—3.30	17.1	24.3	19.1	—
3.30—4.30	10.2	14.1	8.5	—
4.30—5.30	12.5	11.9	6.4	—
Total number of cases.	88	235	47	14

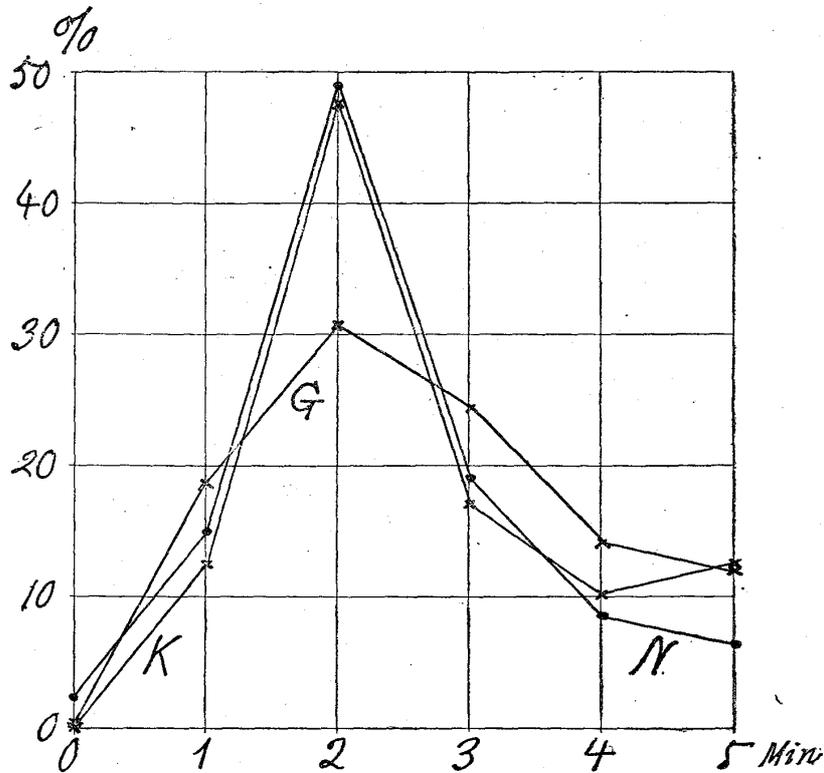


Fig. 3. Relative Frequency of the Different Values of the Time Interval between the Successive Earthquake Occurrences.

K...Kagoshima.

G...Gifu.

N... Nemuro.

The distances of the Kagoshima, Gifu, and Nemro meteorological observatories from the mean centers of disturbance concerned were respectively about 14; 10; and 120 km.

With respect to the interval over 5 minutes, the maximum frequency occurred between 8 min. and 13 min. both at Gifu and Nemro, being similar to the case at Kagoshima (Table V). Taking together the earthquakes at Kagoshima, Gifu, Nemro, and Akita, the frequency was greatest for the interval of 8 to 13 min., attaining the maximum at 10 and 11 min. Should a great number of small shocks occur simultaneously or within the time interval of $\frac{1}{2}$ min. or so from neighbouring points, the result would be a considerable earthquake. A great destructive shock is, however, not followed by such a disturbance, at least not in the same, or a closely lying district. Hence it is conceivable that volcanic earthquakes or after-shocks tend to occur most frequently at certain time intervals, dependent, amongst the others, on the imperfectly elastic condition of the upper part of the earth's crust.*

TABLE IV. SUCCESSIVE TIME DIFFERENCES OF THE EARTHQUAKES OR EARTHQUAKE GROUPS OBSERVED AT THE KAGOSHIMA METEOROLOGICAL OBSERVATORY ON JAN. 11TH AND 12TH, 1914.

(Earthquakes occurring at successive intervals under 5 minutes are treated as forming a single group.)

Time of Earthquake Occurrence.	Number of Eqkes.	Successive Time Difference.	Time of Earthquake Occurrence.	Number of Eqkes.	Successive Time Difference.
Jan. 11th			Jan. 11th.		
$3 \text{ } 40\frac{1}{5}^{\text{h m}} - 3 \text{ } 43^{\text{h m}}$ A.M.	2	$21 \text{ } 42^{\text{m s}}$	$4 \text{ } 45\frac{2}{3}^{\text{h m}}$ A.M.	1	$8 \text{ } 20^{\text{m s}}$
$3 \text{ } 59 - 4 \text{ } 8\frac{1}{3}$	5	11 23	4 54	1	12
$4 \text{ } 15\frac{1}{4}$	1	11 5	$5 \text{ } 03 - 5 \text{ } 7\frac{2}{3}$	3	21 45
$4 \text{ } 26\frac{2}{3}$	1	19 20	$5 \text{ } 27\frac{3}{4}$	1	30 15

* The time intervals between the successive small eruptions of the Asama-yama have been considered in the Bulletin, Vol. VII.

Time of Earthquake Occurrence.	Number of Eqkes.	Successive Time Difference.	Time of Earthquake Occurrence.	Number of Eqkes.	Successive Time Difference.
Jan. 11th.			Jan. 11th.		
$5 \cdot 58$ ^{h m} ^{h m} A.M.	1	$107 \cdot 44$ ^{m s}	$3 \cdot 01$ ^{h m} ^{h m} P.M.	1	$15 \cdot 23$ ^{m s}
$7 \cdot 45 \frac{11}{15}$	1	14 16	$3 \cdot 09 \frac{1}{3} - 3 \cdot 18$	4	20 42
$7 \cdot 59 - 8 \cdot 01$	2	13	$3 \cdot 30 \frac{2}{3} - 3 \cdot 39$	4	14 59
8 13	1	10	$3 \cdot 46 \frac{6}{10} - 3 \cdot 52 \frac{1}{6}$	4	24 35
8 23	1	6 50	$3 \cdot 58 - 4 \cdot 27$	9	27 38
$8 \cdot 29 - 8 \cdot 30 \frac{2}{3}$	2	9 10	$4 \cdot 35 - 4 \cdot 48 \frac{1}{2}$	6	28 38
8 39	1	22 40	$4 \cdot 56 \frac{1}{3} - 5 \cdot 27$	11	36
$8 \cdot 56 - 9 \cdot 07$	1	20 40	$5 \cdot 43 - 5 \cdot 51$	4	12 39
9 21	1	15	$5 \cdot 58 - 6 \cdot 1 \frac{1}{2}$	4	20 17
9 36	1	21	$6 \cdot 14 \frac{1}{3} - 6 \cdot 25$	6	26 50
9 57	1	40 30	6 47	1	6
$10 \cdot 37 \frac{1}{2}$	1	8 8	6 53	1	8
$10 \cdot 45 \frac{2}{3}$	1	13 38	7 1	1	9
10 58	1	13 25	7 10	1	5 15
$11 \cdot 10 \frac{1}{3} - 12 \cdot 30$	2	25 35	$7 \cdot 15 \frac{1}{4}$	1	6 55
$11 \cdot 28 - 11 \cdot 46 \frac{9}{10}$	8	30 15	$7 \cdot 22 \frac{1}{6}$	1	11 17
$0 \cdot 5 - 0 \cdot 9 \frac{1}{2}$ P.M.	2	23 28	$7 \cdot 30 \frac{1}{3} - 7 \cdot 36$	3	8 33
$0 \cdot 27 \frac{1}{6} - 0 \cdot 34$	3	17 50	7 42	1	5
$0 \cdot 43 - 0 \cdot 54$	4	16 02	7 47	1	5
$1 \cdot 4 \frac{7}{12}$	1	19 22	$7 \cdot 51 - 7 \cdot 53$	2	7
$1 \cdot 19 - 1 \cdot 29$	4	24 48	$7 \cdot 58 - 8 \cdot 00$	2	14 54
$1 \cdot 41 \frac{1}{2} - 1 \cdot 54$	7	16 35	$8 \cdot 5 - 8 \cdot 13$	5	11 20
$2 \cdot 01 - 2 \cdot 09$	5	10 40	$8 \cdot 18 - 8 \cdot 34$	8	18 46
$2 \cdot 15 - 2 \cdot 17$	2	7	$8 \cdot 41 - 8 \cdot 51$	10	12 48
2 23	1	10 37	$8 \cdot 55 - 9 \cdot 00$	5	10 18
$2 \cdot 30 \frac{1}{8} - 2 \cdot 36 \frac{5}{12}$	3	11 51	$9 \cdot 7 - 9 \cdot 8$	2	4 30
$2 \cdot 45 \frac{7}{12}$	1	8 57	9 12	1	6
$2 \cdot 54 - 2 \cdot 54 \frac{5}{8}$	2	6 35	9 18	1	5

Time of Earthquake Occurrence.	Number of Eqkes.	Successive Time Difference.	Time of Earthquake Occurrence.	Number of Eqkes.	Successive Time Difference.
Jan. 11th.			Jan. 12th.		
h m h m P.M.		m s	h m h m A.M.		m s
9 23	1	11 10	2 41	1	8
9 28 — 9 39	6	13 10	2 49	1	5
9 44 — 9 52	6	15	2 54	1	10
9 59 — 10 07	6	9 40	3 04	1	
10 11 — 10 13	2	14 35	3 11 — 4 10	31	
10 16 — 10 39	12	21 05	4 23	1	7
10 44 — 10 51	6	10 20	4 30	1	7
10 58	1	5	4 37	1	8
11 03	1	19 49	4 42 — 4 49	4	11
11 09 — 11 37	16	29 11	4 56	1	10
11 51 — 11 53	2	6	5 05 — 5 07	3	12 50
11 58	1	7 24	5 15 — 5 23	6	15 01
Jan. 12th.			5 29 — 5 41	7	26 34
0 03 — 0 09 A.M.	5	10 36	5 47 — 6 15½	11	33 53
0 14 — 0 18	2	7 40	6 25 — 6 47	10	22 12
0 22 — 0 25	3	10 50	6 52 — 7 03	6	17 10
0 32 — 0 35	4	6	7 10 — 7 17	3	10 20
0 40 — 0 41	2	14 20	7 23 — 7 25	2	9
0 51 — 1 00	6	12 10	7 32 — 7 34	3	8
1 06 — 1 08	2	13	7 41	1	6 20
1 20	1	6	7 46 — 7 49	3	19 25
1 26	1	5	8 05 — 8 09	4	28 46
1 31	1	12	8 14 — 8 58	21	36 20
1 43	1	9 30	9 05 — 9 20	10	19 48
1 51 — 1 54	2	14 30	9 26 — 9 37	7	23 54
2 05 — 2 09	2	13	9 41 — 10 07	11	24
2 20	1	9	10 14 — 10 24	6	13 30
2 29	1	12	10 32 — 10 34	2	11

Time of Earthquake Occurrence.	Number of Eqkes.	Successive Time Difference.	Time of Earthquake Occurrence.	Number of Eqkes.	Successive Time Difference.
Jan. 12th.			Jan. 12th.		
h m h m 10 44 A.M.	1	m s 12 20	h m h m 2 33 — 2 37 P.M.	2	m s 8
10 49 — 11 02	6	17 40	2 43	1	32
11 13 — 11 15	2	11	3 15	1	25
11 23 — 11 27	2	12 48	3 40	1	29
11 32 — 11 43	5	29 12	4 09	1	19
0 06 — 0 08 P.M.	2	11 30	4 28	1	38
0 17 — 0 20	2	16 30	5 06	1	40
0 34	1	23	5 46	1	43
0 57	1	9	6 29	1	102
1 06	1	8	8 11	1	62
1 14	1	14	9 13	1	23
1 28	1	52	9 36	1	
2 18 — 2 22	2	15			

TABLE V. INTERVALS BETWEEN THE SUCCESSIVE TIMES OF EARTHQUAKE OCCURRENCE.

Time Interval.	Number of Earthquakes at				Sum.
	Kagoshima.	Gifu.	Nemro.	Akita.	
5 ^m	11	28	3	1	43
6	7	24	9	5	45
7	8	21	4	5	38
8	9	36	12	1	58
9	7	44	5	6	62
10	10	40	9	1	60
11	14	44	9	4	71
12	8	34	4	3	49
13	12	36	10	2	60

Time Interval.	Number of Earthquakes at				Sum.
	Kagoshima.	Gifu.	Nemro.	Akita.	
14 ^m	4	23	4	0	31
15	10	24	5	2	41
16	1	22	6	2	31
17	3	30	3	3	39
18	2	25	4	0	31
19	6	19	6	0	31
20	3	19	1	2	25
21	4	16	4		24
22	3	16	5	3	24
23	4	11	2	2	19
24	2	11	3	1	17
25	3	12	2		17
26	1	12	2		15
27	2	6	2	1	11
28	1	12	2	1	16
29	5	11	3		19
30	2	7	0		9
31	0	7	7	1	15
32	1	5	3		9
33	0	11	0	1	12
34	1	8	2	1	12
35	0	3	2	1	6
36	2	6	2		10
37	0	5	0	1	6
38	1	8	0	1	11
39	0	9	1		10
40	1	6	2		9
41	1	5	2		8
42		5	2		7

Time Interval.	Number of Earthquakes at				Sum.
	Kagoshima.	Gifu.	Nemro.	Akita.	
43 ^m	1	7	1		9
44		4	1		5
45		4	1		5
46		3	5		8
47		3	1		4
48		5			5
49		6			6
50		5	1		6
51		1		1	2
52	1	3	1		5
53		4	2		6
54		1	1		2
55		2			2
56		7			7
57		5			5
58		5	1		6
59		1			1
60		1			1
61		4			4
62	1	2	2		5
63		2	1		3
64		1	1		2
65		2			2
66		0	1		1
67		1		1	2
68		1		1	2
69		0		1	1
70		1			1