

b' , c' , d' , and e' are not widely different respectively from the periods b , c , d , and e , characterizing the Asama-yama eruptions.

The periods prevailing in the motion of the Sakura-jima after-eruptions observed in Kagoshima were approximately equal to those found at the Asama-yama and Usu-san. In the case of the observations at the two latter places, the vibration periods in the eruptive earthquakes and in the volcanic micro-tremors were found to be essentially identical with the slower periods existing in the motion of ordinary earthquakes. A similar relation seems to exist also in the Kagoshima observations.

CHAPTER VI. TROMOMETER OBSERVATION AT FRUSATO OF THE SAKURA-JIMA AFTER-ERUPTIONS.

96. Tromometer observation at Frusato. The portable horizontal pendulum tromometer, of the pointer magnification =200, used in Kagoshima since Jan. 16th, 1914, (§ 30), was taken on Feb. 9th to Sakura-jima and set up at the village of Frusato, 3.8 km. to the S. 45° W. from the centre of the craterlet-zone on the S.E. side of the volcano. The two horizontal pointers of the tromometer were oriented so as to register respectively the motion radial and the motion transverse to the mean origin of the disturbance; the proper pendulum period being 4.5 sec. for each component.

The first series of the tromometer observation at Frusato extended for 112 days from Feb. 9th to May 31st, 1914. The lower craterlets on the S.E., or Nabe-yama, side maintained active outbursts for the several succeeding months; causing in the Autumn next, amongst the others, a serious damage to the rice crop in the vicinity of Kagoshima. At the request of the governor of the

Kagoshima prefecture, who was anxious to know the probable course of the variation in the amount of the precipitation of the injurious ashes, the tromometer observation at Frusato was resumed on Oct. 24th, 1914 and continued for the 79 days till January 10th, 1915; the object being to determine the rate with which the after-eruptions decreased in frequency and intensity. The work of the observation was carried on by my assistant, Mr. H. Krosaka, and by Messres. Atsumi, Ando, Matsuda, and Hirase, of the Kagoshima meteorological observatory. Tables XXV and XXVI give the daily numbers of the after-eruptions and earthquakes registered at Frusato during the two series of the observation.

97. Daily frequency of "larger"* after-eruptions. The daily number of the "larger" disturbances was 124 on Feb. 10th; 87 to 50, with the mean of 71, between the 11th and the 13th; 22 to 16, with the mean of 19.3, between the 14th and the 16th; and 13 to 5, with the mean of 7.3, between the 17th and the 26th; being in the subsequent days much smaller and less than 4, except on March 8th and 29th, whose frequency were respectively 9 and 5.

The marked decrease in the frequency on and after the 14th (February) might be due partly to the occurrence of the Iwo-jima earthquake on the preceding day, the 13th; just in the same way as the recent explosive activity of the Kirishima-yama, Nov. 1913 to Jan. 8th, 1914, was brought to an end by the last great eruption of the Sakura-jima.

The frequent occurrence of the "larger" after-eruptions ended in the Kagoshima observation with Jan. 27th, and in the Frusato observation practically with Feb. 16th, or respectively 15 and 35 days after the commencement of the eruptions on Jan. 12th, corresponding probably to the marked reduction of the eruptive

* For the definition of *large* and *small disturbances*, see the Bulletin, Vol. VIII, p. 26.

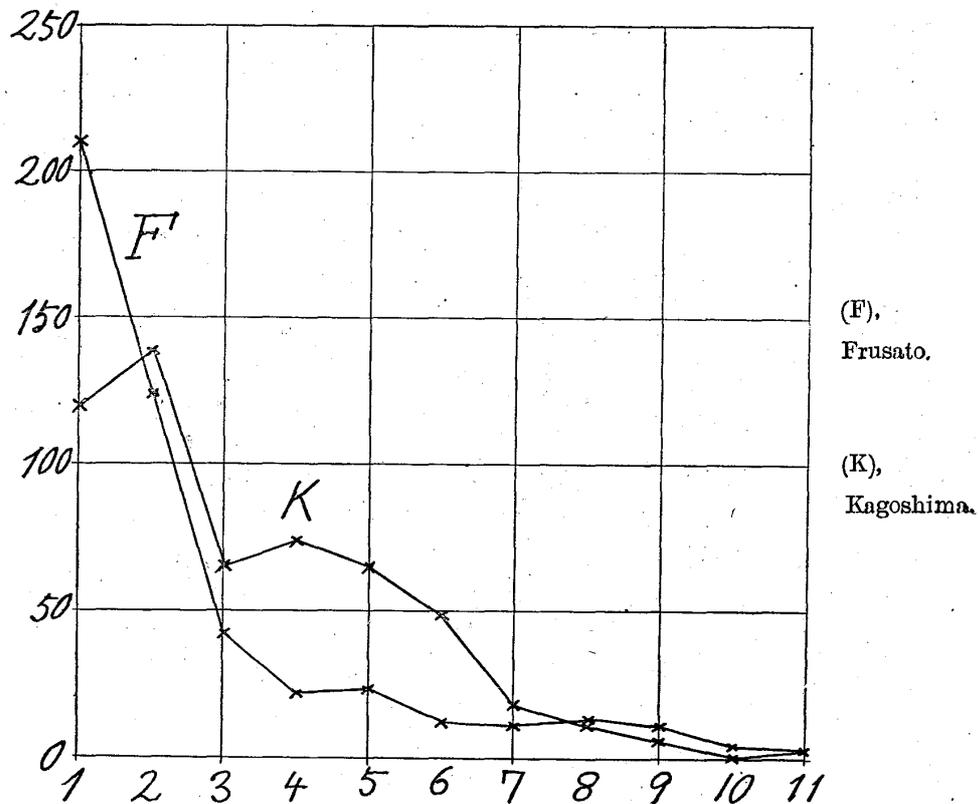
activity of the western, or Yokoyama, side and the eastern, or Nabe-yama, side craterlet groups.

98. Comparison of frequencies of larger after-eruptions registered at Kagoshima and Frusato. In the following list are given the 2-daily numbers of the larger after-eruptions tromometrically registered at Kagoshima and Frusato.

Kagoshima.			Frusato.		
	Days.	Number of Eruptions.		Days.	Number of Eruptions.
Jan.	17-18	120	Feb.	10-11	211
	19-20	139		12-13	124
	21-22	66		14-15	42
	23-24	74		16-17	22
	25-26	65		18-19	23
	27-28	49		20-21	12
	29-30	18		22-23	11
	31-Feb. 1	11		24-25	13
Feb.	2-3	6		26-27	11
	4-5	0		28-March 1	4
	6-7	3	March	2- 3	3
				4- 5	1
				6- 7	5
				8- 9	13
				10-11	4
				12-13	2
				14-15	0
				16-17	0
				18-19	1
				20-21	3
				22-23	2
				24-25	8
				26-27	4
				28-29	5
				30-31	1

In Kagoshima, the two-daily frequency decreased from 120 or 139 to 49 in the course of about 10 or 11 days between 17th–18th to 27th–28th in January, while at Frusato it decreased from 211 to 42 in the course of only about 5 days between 10th–11th to 14th–15th in February.

Fig. 24. Comparison of the 2-daily After-eruption Frequency at Frusato with that at Kagoshima.



The numerals 1, 2, 3... on the abscissa axis correspond to the successive 2-days intervals in the list on p. 442.

As graphically shown in fig. 23, the time relation of the frequency of the after-eruptions was not quite regular in the Kagoshima observation, which was made between Jan. 16th and Feb. 8th. This might be due to the fact that in the case under consideration the tremor-recorder registered the eruptions from the western, or Yokoyama, side group of the craterlets as well as those

from the eastern, or Nabe-yama side, craterlets. As the two different eruption centres exhibited maximum activity at different, and probably alternating, moments, the variation of the total eruption frequency would naturally be not one of a simple decrease. On the other hand, in the case of the Frusato observations, made since Feb. 9th, the eruptions registered were entirely those originating from the Nabe-yama side craterlets, quite close to the seismograph station, the craterlets on the west end of the island having then already been reduced to rest. Consequently the time relation of the eruption frequency found at Frusato was quite simple, being approximately one of rectangular hyperbola.

99. Decrease rate of the frequency of larger after-eruptions.

The relation between the time (x) and the daily frequency (y) of the "larger volcanic disturbances" for the earlier portion of the observations at Frusato can very nearly be represented by the equation

$$\log y = 2.09962 - 0.14187 x, \dots\dots\dots (1)$$

in which $x=0$ denotes the 10th of Feb., 1914. The actual and calculated values of the frequency for $x=0$ to 9 are indicated in the following table:—

Date (Feb. 1914)		Actual.		Calculated (Equation 1).
10th	$x=0$	$y=124$	$y=126$
11th	1	87		91
12th	2	74		65
13th	3	50		47
14th	4	22	} Mean, 19.3	25
15th	5	20		
16th	6	16		
17th	7	6	} Mean, 9.7	9
18th	8	10		
19th	9	13		

If we, however, consider the variation of the number ($=y$) of the eruptions during the successive 10-day intervals ($=x$ whose 0 corresponds to Feb. 10th to 19th, 1914), the rectangular hyperbola equation

$$y = \frac{56.77}{x + 0.137} \dots\dots\dots (2)$$

is found to express the mutual relation with a fair accuracy, as follows:—

x	10-Days Interval. (1914.)	y , actual.	y , calculated.
0	Feb. 10th–Feb. 19th.	422	415
1	„ 20th–March 1st.	51	50
2	March 2nd– „ 11th.	26	} Mean, 17.3 18.1
3	„ 12th– „ 21st.	6	
4	„ 22nd– „ 31st.	20	
5	April 1st–April 10th.	9	} Mean, 9.3 9.2
6	„ 11th– „ 20th.	12	
7	„ 21st– „ 30th.	7	

100. Comparison with Usu-san eruption. (See fig. 24.) In the case of the Usu-san eruption of 1910, the tremor-recorder observation made at Nishi-Monbets between July 31st and Aug. 6th, 1910, has given, for the decrease of the number of the volcanic outbursts, the following relation:*

$$\log y = 0.8691 - 0.1152 x, \dots\dots\dots (2)$$

in which y is the mean hourly frequency of the volcanic disturbances during the 24-hour time x , whose origin corresponds to

* The Bulletin, Vol. V., No. 1, p. 33, Equation (3), for which y is the mean hourly (not the 24-hourly, as by misprint has been put there) frequency of the eruptions during the 24 hours denoted by x .

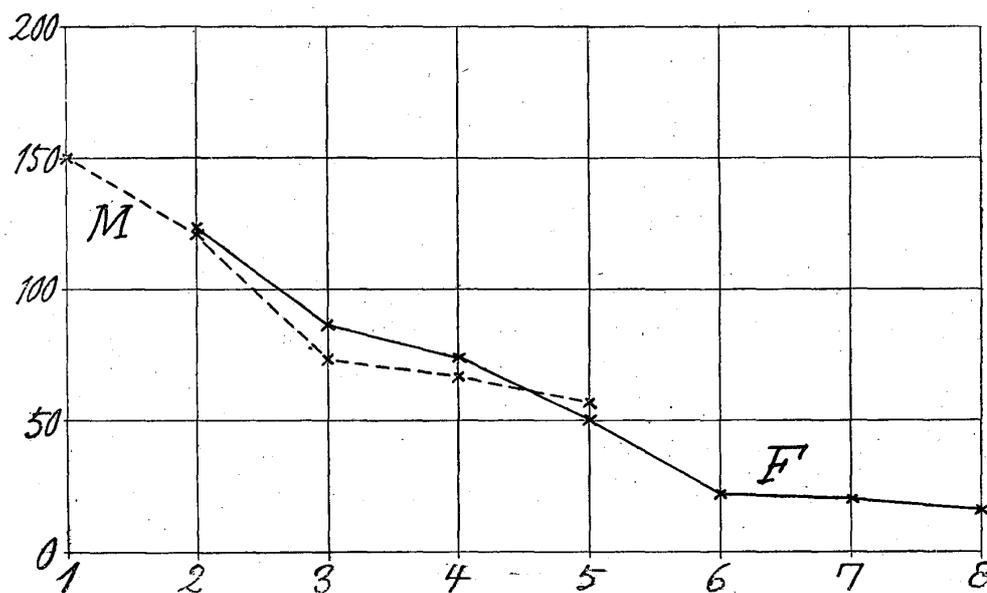
On Aug. 3rd, the observation is wanting for the 6 hours between 2 and 8 A.M., the daily frequency of 73, enclosed in brackets, being $\frac{1}{3}$ of the number of the disturbances recorded during the remaining hours of the day, namely, 55.

the interval from noon, July 31st, to noon, Aug. 1st, or about 6 complete days after the commencement of the eruptions.

The actual and calculated values of the frequency y are as follows:—

Date (Aug. 1910).	x	$24 \times y$ actual.	$24 \times y$ calculated (Eq. 2).
1st	0.5	151	155.5
2nd	1.5	121	119.2
3rd	2.5	55 (73)	91.5
4th	3.5	67	70.2
5th	4.5	57	53.8

Fig 24. Comparison of the Daily Eruption Frequency at Frusato with that at Nishi-Monbets.



F....Sakura-jima After-eruptions (1914) observed at Frusato.
M....Usu-san (Hokkaido) Outbursts in 1910, observed at Nishi-Monbets.

The successive 24-hourly values of the eruption frequency.... 121; 73; 67; and 57 for $x=1.5$; 2.5; 3.5; 4.5;.... for Nishi-Monbets, are nearly equal to those of the daily frequency for $x=0, 1, 2$ for the Sakura-jima, namely, 124; 87; 74; 50; ..; the coefficient of the x in Equation (2) for the former place, being about 0.12, which is not much different from that for the latter.

101. "Small"* after-eruptions. (See Table XXV and figs. 25 and 26.) Up to the 15th of February the small disturbances occurred so close to each other that it was impossible to count their number. For the next 6 weeks or so the individual disturbances could be distinguished more or less definitely; these being, however, very often confused by the volcanic micro-tremors (or oscillations) of fairly good size, which existed continuously. In this way the numbers of the small eruptions between Feb. 16th and the end of March (1914) given in Table XXV are to be regarded as giving only the roughly approximate values of the frequency of the comparatively well-defined small eruptions. Subsequently the motion of the ground was much reduced so that even very small disturbances could be counted with a tolerable degree of accuracy. This accounts partly for a marked frequency increase at the commencement of April.

According to Table XXV, the maximum daily number of the small disturbances was about 670, which corresponds to an average rate of one eruption in every 2 minutes. It was only after April 27th, that the daily frequency was reduced to about, or below, 100. From the graphical representation in fig. 25 it can be seen that the first maximum daily frequency (=486) took place on March 13th, the second (absolute) maximum (=672) on April 12th, and the third maximum (=204) on May 12th. It is interesting that these three days corresponded to a high-tide epoch in the Kagoshima bay, the moon having been full on the respective preceding days, namely, March 12th, April 11th, and May 10th. The final steady decrease of the eruptive activity seems to have begun from April 12th, or three months after the first eruption on Jan. 12th.

* See the Bulletin, Vol. VIII, No. 1, p. 26.

Fig. 25. Daily Frequency Variation of the Smaller Sakura-jima After-eruptions
observed tromometrically at Frusato.

Feb. 16th—May 31st, 1914.

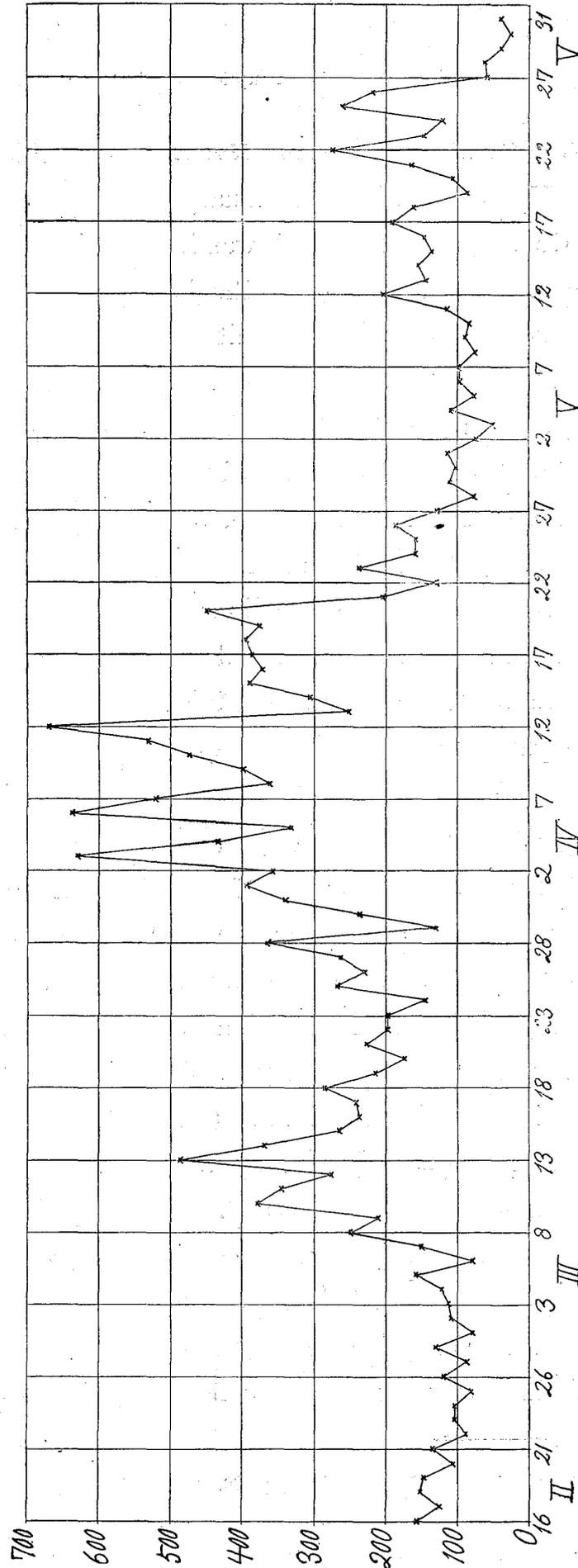


Fig. 26. Tromometer Observation at Irusato: Daily Frequency Variation of the Small Sakura-jima After-eruptions compared with that of the Loud Detonations.

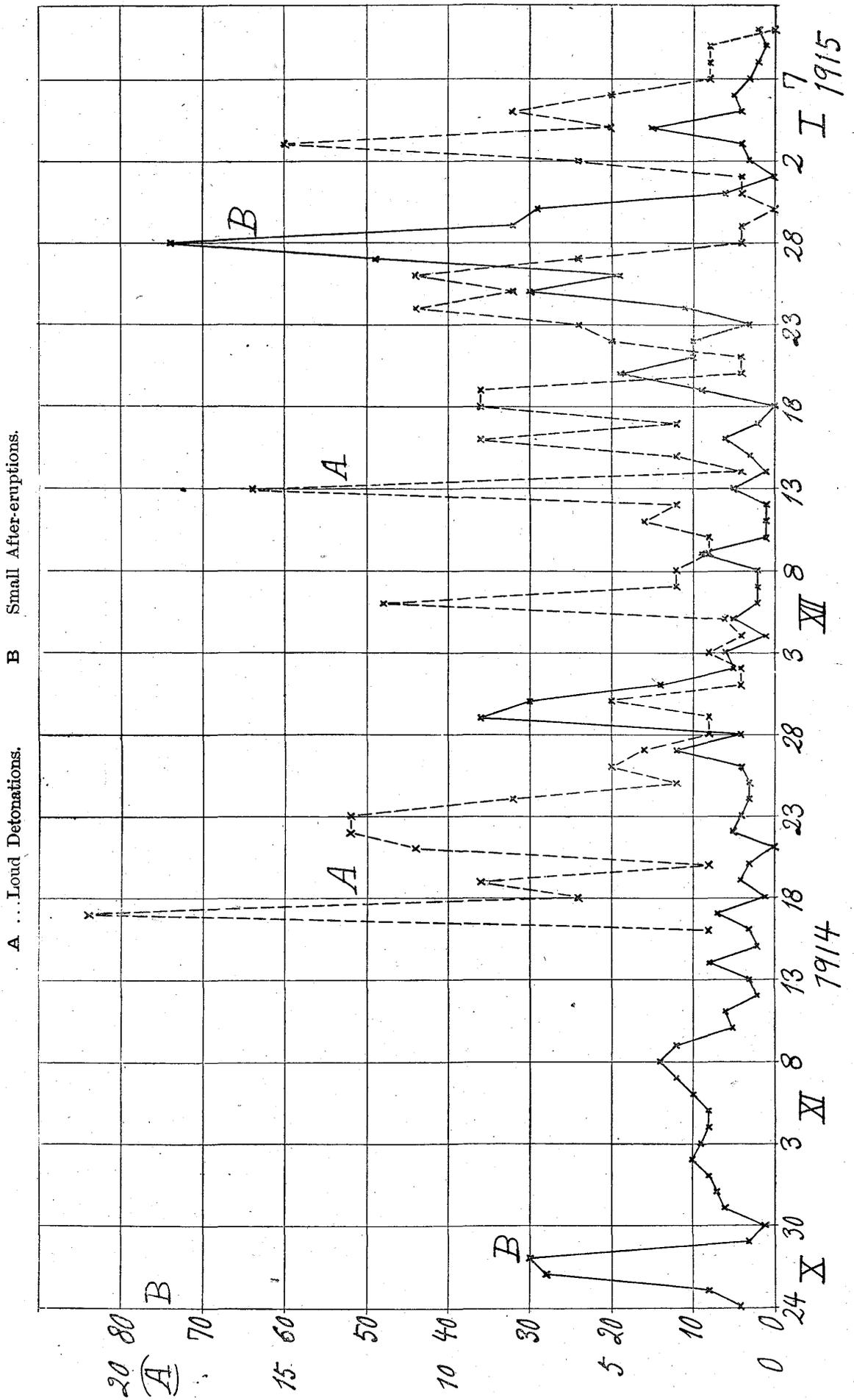


TABLE XXIII. 3-DAILY FREQUENCY VARIATION OF THE SAKURA-JIMA
AFTER-ERUPTIONS TROMOMETRICALLY REGISTERED
AT FRUSATO. FEB.-MAY, 1914.

3-day Interval.		Number of Eruptions.		3-day Interval.		Number of Eruptions.	
		Larger.	Smaller.			Larger.	Smaller.
Month, II,	Days 16-18	443	32	Month, IV,	Days 11-13	1456	2
	19-21	384	25		14-16	1068	5
	22-24	296	17		17-19	1161	3
	25-27	286	18		20-22	783	3
	28-2	317	6		23-25	551	2
III,	3-5	392	2		26-28	390	2
	6-8	478	14		29-1	327	2
	9-11	938	8	V,	2-4	230	2
	12-14	1133	2		5-7	272	3
	15-17	743	0		8-10	246	2
	18-20	672	1		11-13	462	2
	21-23	621	5		14-16	435	6
	24-26	642	9		17-19	438	1
	27-29	760	8		20-22	544	5
	30-1	972	1		23-25	523	9
IV,	2-4	1423	0		26-28	339	3
	5-7	1492	4		29-31	103	6
	8-10	1237	5				

102. *Comparison with "larger" after-eruptions.* The 3-daily numbers of the large and small disturbances, between Feb. 16th and May 31st, are indicated in Table XXIII, the graphical illustration being given in fig. 27. From the latter, it will be observed that the two categories of the eruptions have a tendency of occurring in a symmetrical opposition. In Table XXIV, the 10-daily frequency variation of the larger after-eruptions is compared to that of the smaller. (See fig. 28.)

TABLE XXIV. 10-DAILY FREQUENCY VARIATION OF THE SAKURA-JIMA
AFTER-ERUPTIONS TROMOMETRICALLY REGISTERED AT
FRUSATO. FEB. 10TH, 1914 TO JAN. 10TH, 1915.

10-day Interval.	Number of After-eruptions.	
	Larger.	Smaller.
Feb. 10 — Feb. 19, 1914	422	—
„ 20 — March 1, „	51	1027
March 2 — „ 11, „	26	1917
„ 12 — „ 21, „	6	2775
„ 22 — „ 31, „	20	2373
April 1 — April 10, „	9	4547
„ 11 — „ 20, „	12	4136
„ 21 — „ 30, „	7	1486
May 1 — May 10, „	7	862
„ 11 — „ 20, „	9	1441
„ 21 — „ 30, „	23	1368
Oct. 24 — Nov. 2, „	7	98
Nov. 3 — „ 12, „	3	81
„ 13 — „ 22, „	4	32
„ 23 — Dec. 2, „	8	107
Dec. 3 — „ 12, „	0	30
„ 13 — „ 22, „	1	64
„ 23 — Jan. 1, 1915	3	250
Jan. 2 — „ 10, „	6	33

103. Earthquake frequency. The non-eruptive volcanic earthquakes were extremely few, there being only 10 between Feb. 15th and March 29th; while there was none of these after the latter date. It seems that the *frequent* occurrence of the earthquakes practically ended on Feb. 15th.

Fig. 27. Comparison of the 3-daily Frequencies of the Larger and Smaller Sakura-jima After-eruptions observed at Frusato.

Feb. 16th—18th ... May, 29th—31st, 1914.

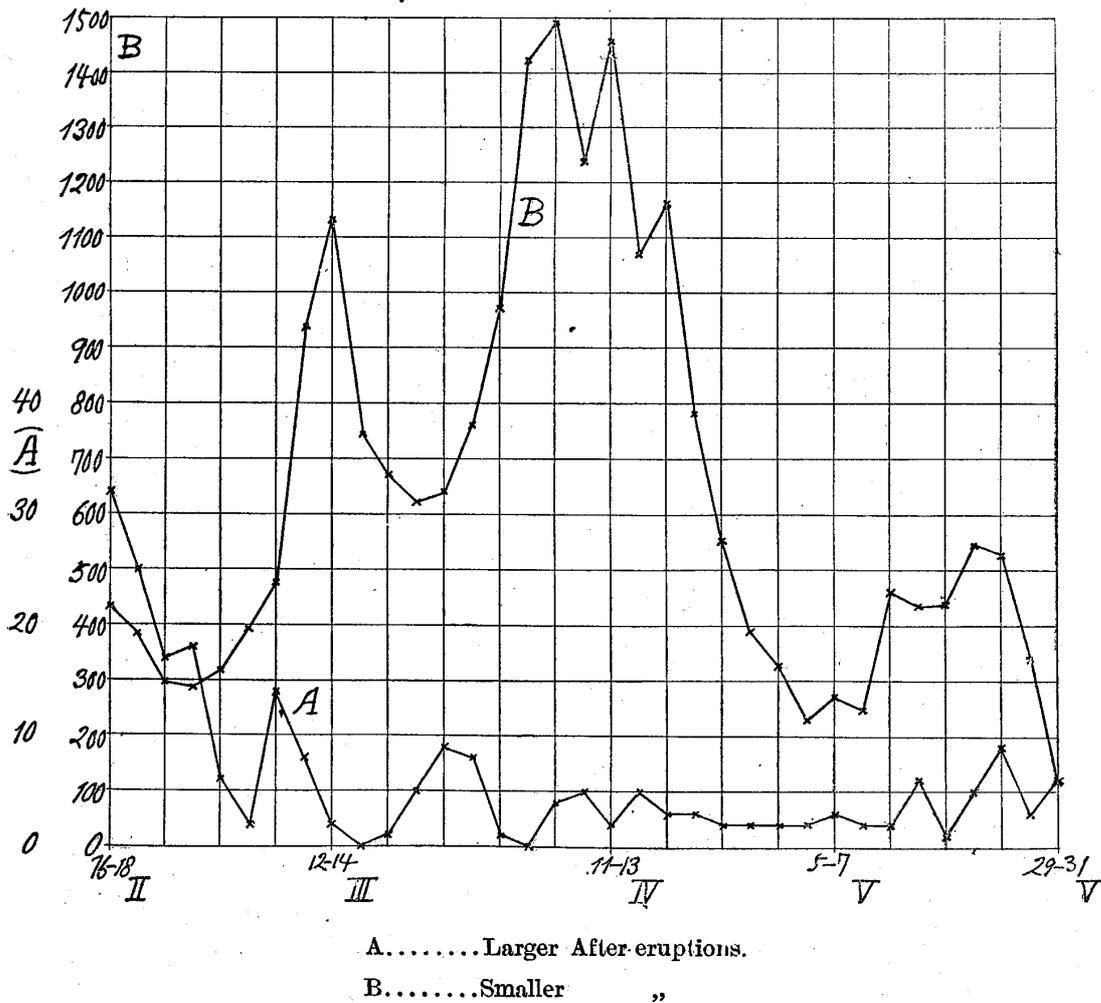
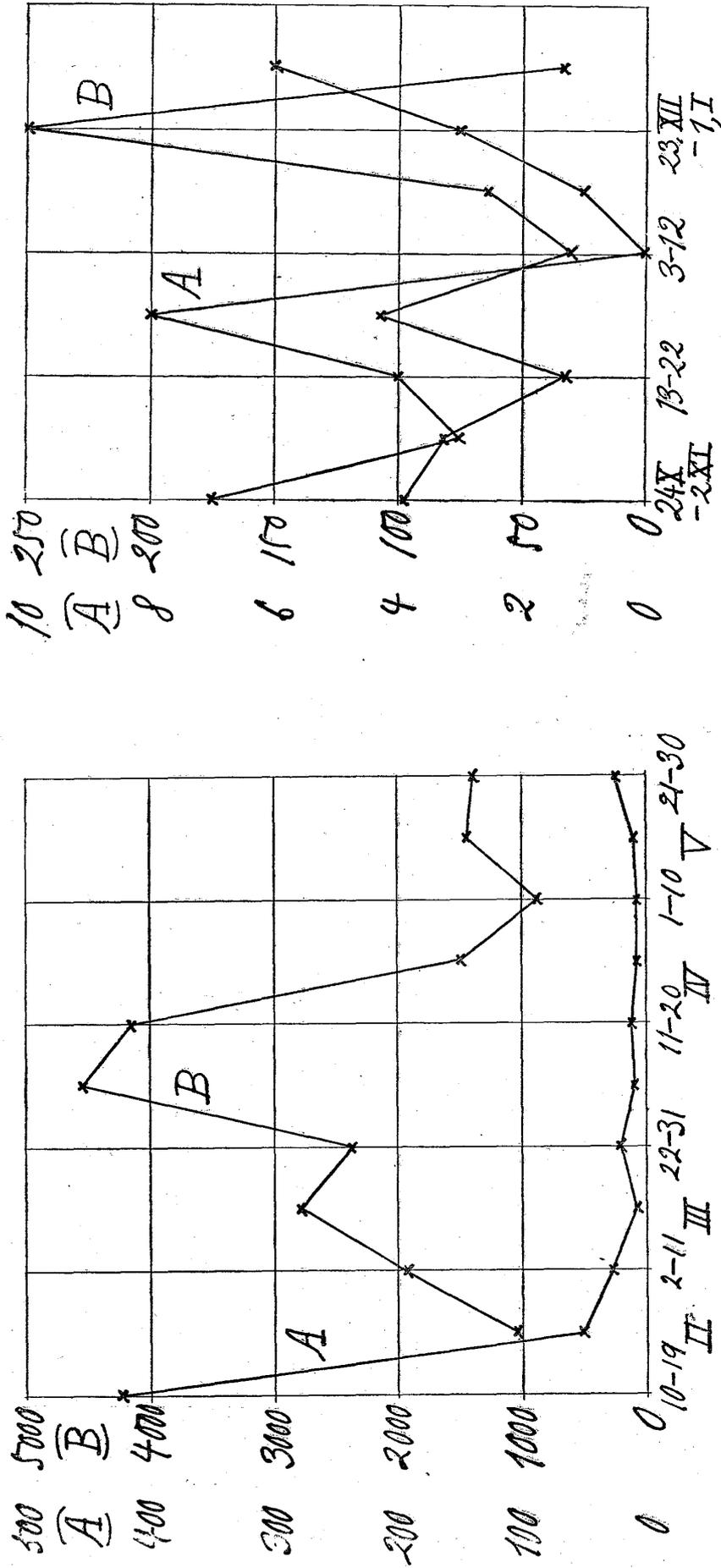


Fig. 28. 10-daily Frequency Variation of the Larger and Smaller Sakurajima After-eruptions observed at Frusato.

A... Larger After-eruptions. B... Smaller After-eruptions.



Feb. to May, 1914,

Oct., 1914, to Dec., 1915,

TABLE XXV. DAILY NUMBERS OF THE SAKURA-JIMA AFTER-ERUPTIONS
AND EARTHQUAKES TROMOMETRICALLY REGISTERED AT
FRUSATO, FEB. 9TH—MAY 31ST, 1914.

Date. (1914.)	Daily Number of After-eruptions.		Volcanic Earthquakes not accompanied by outbursts.
	Larger.	Smaller.	
February, 9 ⁽¹⁾	6	(Continuous.)	—
10	124	„	1 (unfelt.)
11	87	„	—
12	74	„	—
13	50	„	1 ⁽²⁾
14	22	„	8 ⁽³⁾
15	20	„	—
16	16	156	—
17	6	125	1
18	10	152	—
19	13	147	—
20	5	104	—
21	7	133	—
22	6	88	—
23	5	104	—
24	6	101	—
25	7	81	—
26	8	119	—
27	3	86	—
28	2	130	—
March, 1	2	78	—
2	2	109	1
3	1	112	—
4	—	122	—

(1) Registration commenced from 11^h 13^m P.M.

(2) Earthquake of Iwō-jima.

(3) Of these 8, three were of *moderate* intensity, three were *slight*, one was *unfelt*, and the remaining one was of the Iwō-jima origin.

Date. (1914.)	Daily Number of After-eruptions.		Volcanic Earthquakes not accompanied by outbursts.
	Larger.	Smaller.	
March, 5	1	158	2
6	1	78	—
7	4	151	—
8	9	249	—
9	4	211	2
10	3	381	—
11	1	346	—
12	1	277	—
13	1	486	1
14	—	370	—
15	—	265	—
16	—	236	1
17	—	242	—
18	1	285	—
19	—	214	—
20	—	173	—
21	3	227	—
22	1	197	—
23	1	197	—
24	4	144	—
25	4	268	—
26	1	230	—
27	3	263	—
28	—	367	—
29	5	130	2
30	1	237	—
31	—	340	—
April, 1	—	395	—
2	—	358*	—

* Almost continuous.

Date. (1914.)	Daily Number of After-eruptions.		Volcanic Earthquakes not accompanied by outbursts.
	Larger.	Smaller.	
April, 3	—	631*	—
4	—	434*	—
5†	1	304 (332)*	—
6†	1	425 (638)*	—
7	2	522*	—
8	2	362*	—
9	2	400*	—
10	1	475*	—
11	1	532*	—
12†	1	636 (672)*	—
13†	0	176 (252)*	—
14	2	305*	—
15	2	390*	—
16	1	373*	—
17	0	387*	—
18	2	397	—
19	1	377	—
20†	2	428 (451)*	—
21†	1	189 (203)*	—
22	0	129	—
23	1	237	—
24	1	157	—
25	0	157	—
26	1	187	—
27	0	128	—
28	1	75	—
29	2	110	—
30	0	103	—
May, 1†	0	110 (114)	—

† See foot-note on next page.

Date. (1914.)	Daily Number of After-eruptions.		Volcanic Earthquakes not accompanied by outbursts.
	Larger.	Smaller.	
May, 2	0	73	—
3†	1	45 (49)†	—
4	1	108	—
5	0	77	—
6	1	97	—
7	2	98	—
8	0	74	—
9	2	89	—
10	0	83	—
11	—	115	—
12	1	204	—
13†	1	135 (143)	—
14†	3	123 (153)	—
15	3	136	—
16	—	146	—
17	1	192	—
18	—	160	—
19	—	86	—
20	—	106	—
21	2	164	—
22	3	274	—
23	2	147	—
24	1	120	—
25	6	261	—
26	1	219	—
27	—	58	—
28	2	62	—
29	3	38	—
30	3	25	—
31	—	40	—

† Observation wanting for some time interval. The approximate daily frequency (enclosed in brackets) have been deduced by proportion from the actual observed value.

TABLE XXVI. DAILY NUMBER OF THE SAKURA-JIMA DETONATIONS
AND AFTER-ERUPTIONS TROMOMETRICALLY REGISTERED AT
FRUSATO. OCT. 24TH, 1914 TO JAN. 10TH, 1915.

Date.	Daily Number of Detonations.		Daily Number of After-eruptions.		Volcanic Earthquakes not accompanied by outbursts.
	Strong.	Feeble.	Larger.	Smaller.	
1914					
October 24	1		0	4	
25	9		0	8	2
26	3		1	27	3
27	3		0	30	2
28	0		1	2	
29	0		0	1	1 (sensible)
30	1		2	4	
31	1		1	6	
November 1	2		0	8	
2	2		2	8	
3	5		1	8	
4	2		1	7	1
5	4		0	8	
6	3		0	10	
7	5		1	11	
8	2		—	14	
9	0		—	12	
10	2		1	4	
11	5		1	5	
12	0		—	2	
13	1		—	3	
14	1		1	7	
15	0		—	2	
16	1	1	—	3	
17	10	11	1	6	
18	2	4	1	—	

Date.	Daily Number of Detonations.		Daily Number of After-eruptions.		Volcanic Earthquakes not accompanied by outbursts.
	Strong.	Feeble.	Larger.	Smaller.	
1914					
November 19	2	7	—	4	
20	0	2	—	3	
21	6	5	—	—	
22	10	3	1	4	
23	10	3	2	2	
24	6	2	1	2	
25	0	3	1	2	
26	2	3	1	3	
27	1	3	1	11	
28	1	1	—	4	
29	1	1	—	36	
30	0	5	1	29	
December 1	0	1	—	14	
2	0	1	1	4	
3	0	2	—	6	
4	0	1	—	1	
5	3	3	—	5	
6	2	10	—	2	
7	0	3	—	2	
8	0	3	—	2	
9	0	2	—	9	
10	0	2	—	1	
11	2	2	—	1	
12	0	3	—	1	
13	2	14	—	5	
14	0	1	—	1	
15	0	3	—	3	
16	1	8	—	6	

Date.	Daily Number of Detonations.		Daily Number of After-eruptions.		Volcanic Earthquakes not accompanied by outbursts.
	Strong.	Feeble.	Larger.	Smaller.	
1914					
December 17	0	3	1	1	
18	1	8	—	—	
19	0	9	—	9	
20	0	1	—	19	
21	0	1	—	10	
22	1	4	—	10	
23	1	5	—	3	
24	3	8	—	11	
25	2	6	—	30	
26	5	6	—	19	
27	3	3	—	49	
28	0	1	1	73	
29	0	1	—	32	
30	0	0	—	29	
31	1	0	2	4	
1915					
January 1	0	1	—	—	
2	0	6	2	1	
3	11	4	1	3	
4	0	5	—	15	
5	6	2	1	3	
6	3	2	—	5	
7	1	1	—	3	
8	1	1	—	2	
9	1	1	—	1	
10			2	—	

TABLE XXVII. MEAN DAILY BAROMETRIC PRESSURE IN KAGOSHIMA,
FEB. TO MAY, 1914. 700 mm. +

(Reduced to Sea-level and Standard Gravity.)

Month, Year. Day.	II, 1914.	III, 1914.	IV, 1914.	V, 1914.	X, 1914.	XI, 1914.	XII, 1914.	I, 1915.
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
1	65.25	65.72	61.08	62.32	58.78	70.01	65.34	66.99
2	64.75	57.47	56.05	61.13	64.52	70.37	63.67	66.24
3	67.42	62.11	61.19	64.35	66.19	67.32	65.11	66.77
4	68.43	63.70	61.77	65.88	65.30	62.76	63.67	69.41
5	64.70	63.35	62.81	63.02	64.06	61.71	62.64	69.34
6	62.33	56.71	63.12	61.62	63.69	63.92	62.80	67.82
7	65.00	58.51	60.03	59.81	60.90	66.73	66.04	57.97
8	59.10	60.65	61.20	60.40	60.69	67.29	68.59	60.02
9	63.37	59.51	65.52	59.50	62.58	63.53	69.45	67.16
10	66.08	61.96	65.22	58.17	62.66	65.42	68.20	65.39
11	64.90	59.94	63.01	63.67	60.99	68.75	65.60	60.00
12	66.98	59.67	62.05	58.43	62.55	66.38	62.91	64.00
13	68.62	58.17	56.63	59.67	64.70	64.89	65.60	68.39
14	69.95	60.73	56.88	57.40	65.64	61.48	64.60	71.01
15	66.55	67.60	60.62	56.33	66.05	63.11	63.21	72.26
16	64.96	69.25	58.91	57.04	67.01	65.87	65.83	69.36
17	66.66	66.96	62.90	60.35	67.12	64.49	66.14	70.46
18	60.88	65.78	67.03	62.52	64.59	61.25	66.06	70.98
19	60.83	69.58	66.28	60.09	62.59	62.31	67.06	64.14
20	62.27	66.35	61.10	55.11	61.96	59.34	66.49	64.75
21	62.37	61.97	62.41	56.60	66.63	61.16	64.61	67.46
22	61.62	61.75	61.70	63.90	67.50	65.08	56.49	66.54
23	61.58	58.60	58.15	61.61	68.42	66.55	60.52	67.04
24	65.85	57.67	56.21	58.14	67.67	62.34	68.11	69.87
25	62.22	62.32	57.37	63.39	64.57	65.09	67.07	71.51
26	63.80	66.22	60.38	65.36	64.67	66.34	65.20	71.12
27	69.10	70.54	56.21	62.41	64.43	67.35	71.01	66.42
28	70.22	70.93	56.90	58.40	63.27	70.30	71.70	60.75
29		67.59	62.37	54.86	61.68	69.24	70.06	68.60
30		58.61	64.39	57.95	61.99	67.59	69.15	70.52
31		60.67		60.44	67.10		67.59	65.20
Mean.	64.85	62.92	60.98	60.00	64.21	65.27	65.82	67.02