

Report on the Observation of Pulsatory Oscillations in Japan. 2nd Paper.

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With Pls. XXXII—XXXVI.

1. Introduction. In the present note I give an account of a few cases of the pronounced storms of pulsatory oscillations observed on the Asama-yama and in Tokyo and Osaka, with some remarks on the nature and cause of these small slow movements of the ground, which are always going on more or less, especially in localities of extensive new formations. It may here be noted that Tokyo and Osaka are situated respectively at the heads of the Tokyo and the Osaka Bays, small inlets on the Pacific side of the Main Island, while the Asama-yama, whose recent extraordinary activity began from 1908, stands in the central part of the latter, its nearest distances to the Pacific and the Japan Sea coasts being respectively 140 and 90 km. The mutual distances between the two cities and the volcano are as follows:—

Asama-yama to Tokyo (Seismological Institute).....137 km.

„ „ Osaka (Met. Observatory)330 „ „

Tokyo (Seism. Inst.) to Osaka (Met. Obs.)410 „ „

2. Observations on Asama-yama, 1912. The seismographs in the Yuno-taira Seismological Observatory,* on the Asama-yama,

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

1922 metres above sea-level, often recorded small but distinct pulsatory oscillations. In Table I are given the average period and maximum range of motion (2a) of these movements, measured from the diagrams furnished by a 150-times magnification Horizontal Pendulum Tromometer set up for recording the motion parallel to the line connecting the observatory with the crater, or approximately in an ENE-WSW direction, on the following dates:—

- (1) Aug. 31st—Sept. 1st, 1912.
- (2) Sept. 21st—24th, ,,
- (3) Oct. 1st—3rd, ,,
- (5) ,, 16th—21st, ,,

The tromometer in question was similar to that in use at the Seismological Institute since 1902* with improvements in the method of joining the multiplying lever to the prolonged end of the horizontal strut. The average period of the pulsations was in each case measured from a number, generally about 10, of the well-defined and regular consecutive vibrations with apparently equal period. Fig. 1 is a reproduction of a part of the Asamayama diagram obtained in the night of the 18th to 19th, Oct. 1912.

It is interesting that the 3rd among the above-mentioned time intervals, in each of which the pulsatory oscillations were most markedly shown, coincided with an epoch of the eruptive activity of the volcano, whose outbursts took place for several hours on Oct. 2nd. The courses of the cyclones, which caused the storms of pulsatory oscillations in the different cases, are briefly indicated below.

- (1) *Bonin Islands Storm on Aug. 29th—Sept. 2nd.* The de-

* See the *Publications*, No. 12.

pression, which appeared in the morning of Aug. 29th in the neighbourhood of the Mariana Islands, passed over the Chichishima of the Bonin group at about 4 a.m. on the 31st, (lowest pressure=721.4 mm.), reached the Hachijo-jima at about 8 a.m. on Sept. 1st, then changed the course towards NNE and passed over the sea off the SE coast of the Awa-Kazusa peninsula. In Tokyo, the minimum barometric pressure of 736.6 mm occurred at 3.30 p.m., on the 1st. The centre was found to the east of the Kinkazan Island in the morning of the 2nd, thence passing to the SE of Hokkaido. The average translation velocity was 25 km per hour.

(2) *Storm on Sept. 23rd.* The cyclone, which originated in the morning of the 19th to the NW of the island of Yap, progressed to the E. of Luzon, and changed during the ensuing night its course toward the NE in the neighbourhood of the Miyako Island. It appeared on the sea about 120 miles to the S. of Okinawa (Lyukyu) in the morning of the 21st, reaching the Cape Muroto (Tosa, Shikoku) about the midnight of the 22nd. Thence it crossed over the eastern part of Shikoku and the Osaka and Kyoto districts, emerging to the Japan Sea off the coast of Echizen at about 6 a.m. on the 23rd. It then rapidly passed close off the NW coast of the Main Island, till it crossed again the NW corner of the latter at 2 p.m., on the same day, passing then over Hokkaido into the Okhotsk Sea. The lowest barometric pressure observed on the 23rd at the different meteorological stations were as follows: 711.3 mm, Wakayama, 3.10 a.m.; 714.9 mm, Osaka, 3.30 a.m.; 718.0 mm, Tsuruga, 5. a.m.; 730.6 mm, Nagano, 7.30 a.m.; 740.7 mm, Tokyo, 10 a.m.; 727.6 mm, Aomori, 2 p.m.; 731.9 mm, Nemuro, 9.20 p.m.. The translation velocity of the centre was about 15 km per hour between Lyukyu and Central Japan, being

increased to 107 km per hour while crossing over the North Japan.

(3) *Lyukyu and Kyushu Storm of Oct. 1st.* The cyclone, which appeared on Sept. 28th in the channel between Formosa and Luzon, reached the Ishigaki-jima at about 4.40 p.m. on the same day, when the barometric pressure was lowered to 737 mm. The centre then progressed to the NW of the Okinawa Island, passing over the vicinity of Kagoshima at 4 a.m. on Oct. 2nd, when the barometric pressure was reduced to 729.8 mm. Then it crossed with decreasing intensity over the Islands of Kyushu and Shikoku, till it disappeared on the morning of the 14th at the eastern part of the Inland Sea. The translation velocity of this storm was extraordinarily slow, being only about 20 km per hour.

(4) *Oct. 15th-17th.* On the one hand, the cyclone, which appeared in the Yangtse Valley on the 14th, crossed the northern part of the Japan Sea on the 15th, reaching Karafuto on the 16th, with the lowest barometric pressure of 738 mm. On the other hand, a barometric low pressure centre of about 742 mm. came into existence in the morning of the 17th about 1600 km off the S. coast of the Main Island. This, however, soon disappeared.

TABLE I. AVERAGE PERIOD AND MAX. 2a OF THE PULSATORY OSCILLATIONS OBSERVED ON THE ASAMA-YAMA, 1912.

Time.	Average Period.	Max. 2a.	Remarks.
5 $\frac{3}{4}$ p.m., Aug. 31st, to 6 $\frac{2}{3}$ a.m., Sept. 1st, 1912.	3.5sec.	0.0033mm.	
	3.9	33	
	7.2	67	
	7.7	80	
	7.8	80	
	8.1	67	

Time.	Average Period.	Max. 2a.	Remarks.
Sept. 21st to 24th, 1912.			
5.50 a.m. to 5.12 p.m., 21st.	6.8sec.	0.0027mm.	
	7.0	27	
	7.0	33	
	7.1	40	
	7.2	33	
	7.3	40	
	7.5	40	
	7.5	27	
5½ p.m., 21st, to 6 a.m. 22nd.	6.8	13	
	7.3	33	
	7.4	40	
	7.4	33	
	7.6	33	
	7.6	40	
	7.7	40	
	7.8	33	
6 a.m. to 5½ p.m., 22nd.	7.4	53	
	7.8	60	
	7.8	47	
	7.8	53	
	7.9	60	
	8.0	47	
	8.1	73	
	8.2	33	
	8.2	67	
	8.7	53	
5½ p.m., 22nd, to 6½ a.m., 23rd.	4.5	0.0120	
	5.2	0.0047	
	6.0	73	
	7.3	60	

Time.	Average Period.	Max. 2a.	Remarks.
5½ p.m., 22nd, to 6½ a.m., 23rd. (Cont.)	7.4sec.	0.0186mm.	
	7.5	0.0093	
	7.9	0.0093	
	8.0	0.0140	
	8.2	0.0093	
6¾ a.m. to 5 p.m., 23rd.	4.1	0.0053	The pulsatory oscillations attained the maximum activity during the night of 22nd-23rd.
	5.8	0.0113	
	6.3	0.0067	
	6.4	0.0100	
	6.8	180	
	7.2	107	
	7.3	127	
7.5	100		
5 p.m., 23rd, to 6¼ a.m., 24th.	5.4	47	The motion was small and irregular, there being traces of still quicker movements.
	5.7	20	
	5.9	33	
	6.3	40	
	6.4	40	
	6.6	53	
7.1	67		
6½ a.m. to 5½ p.m., 24th.	4.7	27	The motion was small, but regular.
	4.8	20	
	4.9	27	
	5.4	27	
	5.4	20	
	5.5	27	
Oct. 1st and 2nd, 1912.			
6½ a.m. to 6.50 p.m., 1st.	6.0	60	
	6.0	67	
	6.2	33	

Time.	Average Period.	Max. 2a.	Remarks.
6½ a.m. to 6.50 p.m., 1st. (Cont.)	6.2 ^{sec.} 6.4	0.0047mm. 67	
7 p.m., 1st, to 8 a.m., 2nd.	6.0 6.0 6.4 6.5 6.7 6.8	40 33 33 33 40 33	
8 a.m. to 7¼ p.m., 2nd.	4.5 4.7 4.8 5.3 5.4 5.4 5.5 5.6 5.7 5.9 6.0 6.1 6.3 6.4 6.4 6.4 6.4 6.4 6.5 6.5 6.6 6.6 6.6 6.8 6.9	12 17 24 72 34 32 42 50 44 34 22 71 57 67 61 0.0134 0.0079 0.0069 0.0064 0.0104 0.0067 0.0055 0.0094 0.0118 0.0067	

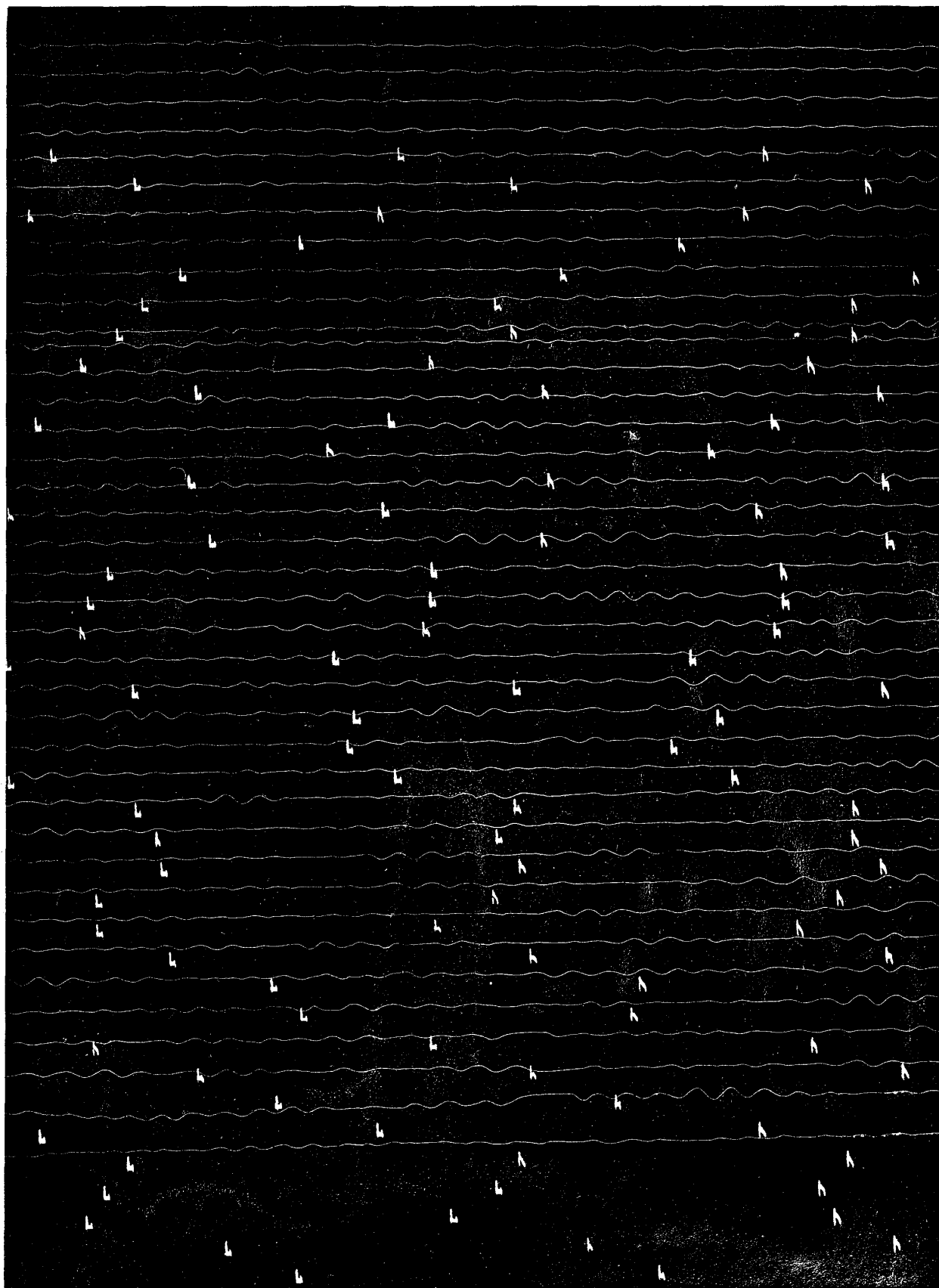
Time.	Average Period.	Max. 2a.	Remarks!
8. a.m. to $7\frac{3}{4}$ p.m., 2nd. (Cont.)	7.2sec. 7.5	0.0045mm. 17	
$7\frac{3}{4}$ p.m., 2nd, to $8\frac{4}{5}$ a.m., 3rd.	6.2 6.3 6.4 6.4 6.4 6.6	60 40 80 53 33 60	Motion regular and well de- fined.
$8\frac{5}{8}$ a.m. to $8\frac{1}{2}$ p.m., 3rd.	6.0 6.2 6.4 6.8 6.9	67 33 33 33 40	

Oct. 16th to 21st, 1912.

$8\frac{1}{2}$ p.m., 16th, to 9 a.m., 17th.	3.4 3.7 4.2 4.4 4.5 4.5 4.5 4.5 4.6 4.6	13 13 33 27 27 27 27 33 20 33	
9 a.m., 17th, to 9 a.m., 18th.	4.8 5.0 5.1 5.2 5.4	13 27 27 27 27	

Fig. 1. Pulsatory Oscillations on Oct. 18th-19th, 1912, observed at the Yuno-taira
Seismological Observatory on the Asama-yama.
ENE-WSW Component.

(End)



→

(Commencement)

Magnification=150. Time-tick interval=1 minute.

Time.	Average Period.	Max. 2a.	Remarks.
9 a.m., 17th, to 9 a.m., 18th. (<i>Cont.</i>)	5.6sec. 5.7 6.8 7.1 7.2	0.0020mm. 27 13 20 20	
9 a.m. to 10 $\frac{1}{2}$ p.m., 18th.	4.8 5.1 5.3 5.3 5.4 5.6 5.7 5.8 6.5 7.2	40 67 33 60 27 53 40 40 47 33	
10 $\frac{1}{2}$ p.m., 18th, to 9 a.m., 19th.	6.1 6.2 6.2 6.4 6.4 6.4 6.5 6.5 6.6 6.7 6.8 6.9 7.0	87 87 93 73 73 0.0146 0.0073 80 87 60 67 93 67	The motion consisted of regular well-defined vibrations, and reached the maximum activity during the night of the 18th-19th.
9 a.m. to 9 $\frac{1}{2}$ p.m., 19th.	5.6 5.7	27 60	

Time.	Average Period.	Max. 2a.	Remarks.
9 a.m. to 9 $\frac{1}{2}$ p.m., 19th. (Cont.)	5.8sec. 5.9 6.0 6.0 6.6 6.9	0.0040mm. 53 53 60 67 40 33	
9 $\frac{1}{2}$ p.m., 19th, to 8 $\frac{4}{5}$ a.m., 20th.	5.4 5.5 5.6 5.6 6.0	53 27 33 33 27	
9 a.m. to 9 $\frac{1}{2}$ p.m., 20th.	5.6 5.6 5.8 6.7 6.7 7.1 7.3	33 40 30 40 40 30 33	The vibration period became lengthened again toward the evening of the 20th.
9 $\frac{1}{2}$ p.m., 20th, to 9 a.m., 21st.	6.7 6.7 6.8 7.0	20 27 27 20	

From the above table it will be seen that the range of motion (2a) of the pulsatory oscillations on the Asama-yama was always small, the maximum amount (single component) so far observed being only about 0.019 mm. The frequencies of the different periods were as follows:—

Period.	Frequency.	Period.	Frequency.
4.5 sec.	6	6.4 sec.	16
4.6 	2	6.5 	6
4.7 	2	6.6 	7
4.8 	4	6.7 	6
4.9 	1	6.8 	9
5.0 	1	6.9 	4
5.1 	2	7.0 	4
5.2 	2	7.1 	4
5.3 	3	7.2 	6
5.4 	8	7.3 	5
5.5 	3	7.4 	5
5.6 	8	7.5 	5
5.7 	5	7.6 	2
5.8 	4	7.7 	2
5.9 	3	7.8 	5
6.0 	11	7.9 	2
6.1 	2	8.0 	2
6.2 	6	8.1 	2
6.3 	3	8.2 	3

For the periods of 8.7 sec., and of 3.4 to 4.4 sec., the frequency was either 1 or *nil*. Although the above list is based on the observations in only a few cases, it may be concluded that for the well pronounced pulsatory oscillations on the Asama-yama, the period occurring most frequently was in the 1st place from 6.4 to 6.8 sec., and in the next place from 5.4 to 6.3 sec., and from 6.9 to 7.5 sec.

Of the storms, which caused the pulsatory oscillations under consideration, the deepest was that on Sept. 22nd-23rd, when the barometric pressure was probably reduced to less than 710 mm while the centre was sweeping over the Pacific, before its approach

to the Osaka and Kyoto districts; the cyclone passing on the 23rd to the Japan Sea off the NW coast of the Main Island. It was on this occasion that the absolutely greatest 2a of 0.0186 mm was observed on the Asama-yama. The next greatest 2a's of 0.0146 mm and 0.0134 mm occurred on the 18th-19th and on the 2nd, in October, when the cyclone centres of the barometric pressures of 742 mm and about 730 mm were found respectively at a considerable distance off the S. coast of the Main Island and over Kyushu. On the other hand, the storm on Oct. 15th, of the minimum barometric pressure of about 738 mm, passing over the northern part of the Japan Sea caused no marked effect at the Asama-yama. It seems likely that the cyclones existing over the Pacific are more effective than those over the Japan Sea in producing the pulsatory oscillations at the volcano, although it is nearer to the latter than to the former.

3. Observations in Tokyo. For the sake of comparison I give in Table II the average period and max.2a of the pulsatory oscillations observed at the Seismological Institute (Tokyo) with an EW component Horizontal Pendulum Tromometer* of 120 times magnification and of natural vibration period of 20 sec., on the same four occasions in 1912 considered in the preceding §, namely: Aug.30th to Sept.1st; Sept.20th to 25th; Sept.30th to Oct. 5th; and Oct. 15th to 22nd. The greatest 2a of 0.138 mm occurred on Aug.31st-Sept.1st, when the storm centre passed off the SE coast of the Awa-Kazusa peninsula, at a distance of some 100 km from Tokyo.

* Described in the *Publications*, No. 12.

TABLE II. AVERAGE PERIOD AND MAX. 2a OF THE PULSATORY OSCILLATIONS OBSERVED IN TOKYO, 1912.

Time.	Average Period.	Max. 2a.	Remarks.
Aug.30th to Sept.1st, 1912.			
10 a.m., 30th, to 10 a.m., 31st, Aug.	5.6sec.	0.0183mm.	
	5.7	450	
	5.8	375	
	5.9	532	
	5.9	850	
	6.2	615	
	6.2	550	
	6.3	225	
	6.4	258	
10½ am., Aug. 31st, to 10½ a.m., Sept. 1st.	2.7	0.0042	
	2.8	50	
	2.9	83	
	5.7	0.1120	
	5.9	0.0690	
	6.2	0.0325	
	7.0	0.0850	
	7.4	0.1000	
	7.7	0.0800	
	7.7	0.1380	
10.50 a.m. to 0.33 p.m., Sept. 1st.	3.2	0.0308	
	3.6	208	
	4.2	910	
	4.2	600	
	4.8	366	
	6.8	0.1020	
	6.8	0.0960	
	6.8	0.0866	
			The motion was irregular.

Time.	Average Period.	Max. 2a.	Remarks.
Sept. 20th to 25th, 1912.			
10 $\frac{1}{2}$ a.m., 20th, to 10 $\frac{1}{2}$ a.m., 21st.	4.9sec.	0.0050mm.	The period lengthened in the morning of the 21st.
	5.0	50	
	5.3	75	
	5.4	50	
	5.4	58	
10 $\frac{1}{2}$ a.m., 21st, to 10 a.m., 22nd.	6.8	0.0100	Motion regular.
	7.1	100	
	7.1	108	
	7.2	100	
	7.4	100	
	7.4	142	
11 a.m., 22nd, to 10 $\frac{1}{2}$ a.m., 23rd.	7.5	0.0291	Motion irregular.
	7.5	216	
	7.8	366	
	7.9	316	
	8.2	241	
	8.3	308	
	9.0	658	
10 $\frac{2}{3}$ a.m., 23rd, to 10 $\frac{1}{2}$ a.m., 24th.	6.3	0.0358	
	6.5	0.1120	
	6.7	0.0650	
	6.9	0.0650	
	7.1	0.0532	
	7.1	0.0624	
10 $\frac{1}{2}$ a.m. to 12 p.m., 24th.	4.8	0.0167	
	4.9	125	
	5.4	216	
	5.5	358	
	5.8	142	

Time.	Average Period.	Max. 2a.	Remarks.
In the morning of the 25th.	3.5sec.	0.0092mm.	
	3.7	0.0083	
	4.4	0.0117	
	4.6	0.0092	

Sept. 30th to Oct. 5th, 1912.

11 a.m., Sept. 30th, to 10 $\frac{1}{2}$ a.m., Oct. 1st.	4.1	0.0116	The motion, which was at first irregular, became gradually regular toward the morning of the 1st.
	5.4	158	
	5.6	175	
	6.1	200	
	6.1	350	
10 $\frac{1}{2}$ a.m., 1st, to 10 $\frac{1}{5}$ a.m., 2nd, Oct.	6.1	0.0500	The motion was large and regular.
	6.1	782	
	6.2	500	
	6.5	532	
	6.5	765	
	6.6	474	
	6.6	550	
	6.6	624	
	6.8	574	
	6.8	366	
10 $\frac{1}{4}$ a.m., 2nd, to 10 $\frac{1}{2}$ a.m., 3rd, Oct.	6.3	0.093	
	6.5	73	
	6.5	67	
	6.8	60	
	6.8	77	
	7.1	50	
	7.1	83	
10 $\frac{3}{4}$ a.m., 3rd, to 10 $\frac{1}{2}$ a.m., 4th, Oct.	5.7	0.0383	The vibrations were irregular, being mixed with smaller ones.
	6.0	450	
	6.7	516	
	6.9	358	
	7.2	375	

Time.	Average Period.	Max. 2a.	Remarks.
10 $\frac{1}{3}$ a.m., 4th, to 10 $\frac{1}{4}$ a.m., 5th, Oct.	6.4sec.	0.0200mm.	The motion became again large and regular.
	6.5	375	
	7.2	316	
	7.2	316	
	7.3	524	
	7.4	341	

Oct. 15th to 22nd, 1912.

11 a.m., 15th, to 10 $\frac{1}{2}$ a.m., 16th.	4.3	0.0083	
	4.6	0.0075	
	4.6	0.0083	
	4.8	0.0092	
	5.1	0.0125	
11 a.m., 16th, to 10 $\frac{1}{2}$ a.m., 17th.	3.9	0.0150	
	4.4	0.0083	
	4.5	0.0200	
	4.7	0.0092	
	5.0	0.0125	
10 $\frac{3}{4}$ a.m., 17th, to 10 $\frac{2}{3}$ a.m., 18th.	4.6	0.0225	The motion became grad- ually irregular, being mixed with slower vibrations.
	4.9	125	
	5.0	133	
	5.0	116	
	5.6	142	
11 a.m., 18th, to 10 $\frac{3}{4}$ a.m., 19th.	6.4	0.1080	The motion was most active between 9 p.m. on the 18th and 5 a.m. on the 19th.
	6.4	0.1020	
	6.4	0.0874	
	6.4	0.0550	
	6.7	0.0582	
	7.0	0.0958	
	5.8	0.0350	

Time.	Average Period.	Max. 2a.	Remarks.
11 a.m., 19th, to 10 $\frac{2}{3}$ a.m., 20th.	5.9sec.	0.0333mm.	
	6.1	308	
	6.5	200	
	6.7	275	
11 a.m., 20th, to 10 $\frac{5}{6}$ a.m., 21st.	7.4	0.0375	The period became short from about 7 a.m. on the 21st.
	7.4	216	
	7.5	367	
	7.7	375	
	7.7	192	
11 a.m., 21st, to 10 $\frac{2}{3}$ a.m., 22nd.	4.6	0.0042	
	4.8	33	
	5.0	42	
	5.2	58	

4. Comparison of pulsatory oscillations observed on Asama-yama and in Tokyo. In Table III are given the max.2a and the general mean period of the pulsatory oscillations observed in the different time intervals on the Asama-yama and in Tokyo. The max.2a's at the two places of observation on the occasions of the several storms were as follows:—

Date (1912).	Max.2a on Asama-yama=I	Max.2a in Tokyo=II	Ratio: II / I
22nd-24th, Sept.	0.0186mm.	0.1120mm.	6.0
1st-3rd, Oct.	0.0134	0.0930	6.9
18th-19th, Oct.	0.0146	0.1080	7.4
Aug. 31st-Sept. 1st.	0.0080	0.1380	17.3
Mean.	9.4

Thus the *amplitude* of the pulsatory oscillations on the Asama-yama was always very small, being in the cases under consider-

ation only from about $1/6$ to $1/17$ of that in Tokyo. It has of course been known since many years that these non-seismic movements develop themselves only to a slight degree in such mountainous and rocky districts as Miyako, Arima, etc.*

On the other hand, the oscillation *period* did not differ in any marked manner between the Asama-yama and Tokyo, the variation in its mean value from day to day being also practically identical for the two places. Thus, in the case of the storm on Oct. 15th to 22nd, the average period in Tokyo, which was short and equal to 4.5 to 5.0 sec. during the first three days, became lengthened to 6.5 sec. on the 18th and 19th, when the motion attained the maximum activity; becoming still slower with the decreasing amplitude namely, 7.5 sec., on the 20th and 21st. Approximately parallel to the above course, the average oscillation period on the Asama-yama, which was principally 4.5 and 5.3 sec. on the 16th and 17th, became 6.5 sec. on the 18th to 19th in the epoch of the maximum activity, being lengthened to 7.0 sec. on the 20th. Again, in the storm of Sept. 20th to 25th, the oscillation period was, both on the Asama-yama and in Tokyo, 7.2 to 8.0 sec. on the 21st and 22nd, but was shortened to 6.8 sec. on the 23rd, when the motion was of the maximum intensity; being further reduced on the 24th to 5.1 and 5.3 sec. at the two places. In the case of the storm on Oct. 1st to 2nd, the periods of the largest vibrations on the Asama-yama and in Tokyo were respectively 6.3 and 6.5 sec., while in that on Aug. 31st to Sept. 1st the periods at these two places were 7.7 and 6.8 sec.

In Table IV, the maximum amplitudes of the vibrations observed on the Asama-yama and in Tokyo are separately arranged according to magnitude, irrespective of the dates of occurrence;

* The Publications, No. 5, (1901).

the mean period of the different groups being as in the following table:—

Group.	On the Asama-yama.		Group.	In Tokyo.	
	Max. 2a	Mean Period.		Max. 2a	Mean Period.
i	^{mm} 0.0120– ^{mm} 0.0187	6.51 ^{sec.}	i'	^{mm} 0.1020– ^{mm} 0.1380	6.73 ^{sec.}
ii	0.0040–0.0080	6.43	ii'	0.0350–0.0930	6.52
	—	—	ii''	0.0910	4.0
iii	0.0013–0.0033	5.08	iii'	0.0116–0.0225	5.18
	—	—	iv'	0.0033–0.0092	2.8–5.2

Thus in the first two groups, for the movements of max.2a=0.0040 to 0.0187 mm on the Asama-yama, and of max.2a=0.0350 to 0.1380 mm in Tokyo, the average period of the most frequently occurring oscillations was practically constant and approximately equal to $6\frac{1}{2}$ sec. Again, for the movements of max.2a=0.0013 to 0.0033 mm (group iii) on the Asama-yama, and of max.2a=0.0116 to 0.0225 mm (group iii') in Tokyo, the prevailing period at both places was about 5.1 sec. It may hereby be remarked that the amplitudes on the Asama-yama were about one tenth of those in the corresponding groups in Tokyo.

From the facts described above, I conclude that the pulsatory oscillations on the Asama-yama are not proper to the volcano itself, but are, in spite of the great difference in the magnitude of amplitude, essentially similar in character to those in Tokyo, the period on given days being identical at the two places. This inference does not of course exclude the possibility of the production of pulsatory oscillations of different periods on, and in the vicinity of, the Asama-yama consequent to an unusual eruptive activity of the latter, as was the case with the Usu-san eruption of 1910. (See No. 1 of this volume.)

TABLE III. MEAN PERIOD AND MAX. 2a OF THE PULSATORY
OSCILLATIONS ON THE ASAMA-YAMA COMPARED TO
THOSE IN TOKYO, 1912.

Date * (1912)	Asama-yama.		Tokyo.	
	Mean Period.	Max. 2a.	Mean Period.	Max. 2a.
September 20th-25th.				
20th-21st	— sec.	— mm.	5.2 ^{sec.} 4.2	0.0075 ^{mm.} 0.0033
21st	7.2	0.0040	7.2	0.0142
21st-22nd	7.5	0.0040		
22nd	8.0	0.0073	8.0	0.0657
22nd-23rd	{ 7.7	0.0186		
	{ 5.2	0.0120		
23rd	{ 6.8	0.0186	6.8	0.1120
23rd-24th	{ 4.1	0.0053		
	6.2	0.0067		
24th	5.1	0.0027	5.3	0.0358
24th-25th	—	—		
25th	—	—	4.5	0.0116
			3.6	0.0092
Sept. 30th—Oct. 5th.				
30th-1st	—	—	5.5	0.0350
1st	6.2	0.0067	6.5	0.0782
1st-2nd	6.4	0.0040		
2nd	{ 6.3	0.0134	6.7	0.0930
2nd-3rd	{ 4.7	0.0024		
	6.4	0.0080		
3rd	6.5	0.0067	6.5	0.0515
3rd-4th	—	—		
4th	—	—	7.0	0.0375
4th-5th	—	—		

Date. (1912)*	Asama-yama.		Tokyo.	
	Mean Period.	Max. 2a.	Mean Period.	Max. 2a.
Oct. 15th-22nd.				
15th 15th-16th	— sec. —	— mm. —	4.7sec.	0.0125mm.
16th 16th-17th	{4.5 3.6	0.0033 0.0013	4.5	0.0200
17th 17th-18th	{5.3 7.0	0.0027 0.0020	5.0	0.0225
18th 18th-19th	{5.4 6.9 6.5	0.0067 0.0047 0.0146	6.5	0.1080
19th 19th-20th	6.1 5.6	0.0067 0.0053	6.2	0.0350
20th 20th-21st	{7.0 5.7 6.8	0.0040 0.0040 0.0027	7.5	0.0375
21st 21st-22nd	— —	— —	4.9	0.0058
Aug. 30th—Sept. 1st.				
30th-31st	— sec.	— mm.	6.0sec.	0.0850mm.
31st-1st	{7.7 3.7	0.0080 0.0033	{6.8 2.8	0.1380 0.0083
1st	—	—	{6.8 4.0	0.1020 0.0910

* 21st, 22nd, etc. indicate each the time interval from morning to evening of the corresponding day, and 21st-22nd, 22nd-23rd, etc. the time interval from evening of the first given day to the morning of the next.

TABLE IV. MEAN PERIODS CORRESPONDING TO DIFFERENT GROUPS OF AMPLITUDE. ASAMA-YAMA AND TOKYO, 1912.

Asama-Yama.		Tokyo.	
Max. 2a.	Mean Period.	Max. 2a.	Mean Period.
0.187mm.	7.7sec.	0.1380mm.	6.8sec.
167	6.8	1120	6.8
147	6.5	1080	6.5
134	6.3	1020	6.8
120	5.2		
			Average,
			6.73sec.
			(i')
		0.0930	6.7
0.0080	7.7	850	6.0
90	6.4	782	6.5
73	8.0	657	8.0
67	6.2	515	6.5
67	6.2	375	7.5
67	6.1	375	7.0
67	5.4	358	5.3
67	6.5	350	5.5
53	5.6	350	6.2
53	4.1		
47	6.9	0.0910	4.0.....(ii'')
40	7.5		
40	7.2	0.0225	5.0
40	7.0	200	4.5
40	6.4	142	7.2
40	5.7	125	4.7
		116	4.5
			Average,
			5.18sec.
			(iii')
0.0033	4.5		
33	3.7	0.0092	3.6
27	6.8	75	5.2
27	5.3	83	2.8
27	5.1	58	4.9
24	4.7	33	4.2
20	7.0		
13	3.6		
			(iv')

5. Observations in Osaka. Table V gives, as an instance of

a case of small motion, the average period and the corresponding max. 2a of the pulsatory oscillations (EW component) in the morning of Dec. 22nd, 1910, observed at the Tokyo Seismological Institute and the Osaka Meteorological Observatory. The 2a's in the two places were widely different, the largest motion in Tokyo being 0.075 mm, or about 5 times that in Osaka. The period was, however, identical at both places, with the mean value of 4.0 sec. in each case.

TABLE V. PULSATORY OSCILLATIONS IN THE MORNING OF DEC. 22ND, 1910, OBSERVED IN TOKYO AND OSAKA.

Tokyo.		Osaka.	
Average Period.	Max. 2a.	Average Period.	Max. 2a.
3.9sec.	0.090mm.	3.8sec.	0.0116mm.
3.9	0.040	3.8	0.0116
4.0	0.075	3.9	0.0067
4.1	0.075	4.1	0.0108
4.1	0.075	4.1	0.0150
		4.1	0.0092
		4.1	0.0100
4.0(mean)		4.0(mean)	

As instances of very large pulsatory oscillations observed in Osaka, I give in Table VI the average period and max. 2a on the following three dates:—

- (i) September 22nd, 1912 (morning),
- (ii) „ „ „ (night.),
- (iii) Jan. 22nd–23rd, 1913;

the measurement having been made from the diagrams furnished by the two similar long-period horizontal pendulum seismographs, each of 20-times magnification, set up in the EW and NS direc-

tions. The general mean period in Osaka on the different occasions was as follows:—

Time.	EW Component.	NS Component.
i	7.0 sec. (Max. $2a = 0.13$ mm)	7.5 sec. (Max. $2a = 0.13$ mm)
ii	6.0 „ („ = 0.30 „)	5.8 „ („ = 0.365 „)
iii	5.3 „ („ = 0.17 „)	6.2 „ („ = 0.17 „)
Mean	6.3 sec.	6.5 sec.

It will be seen that in the given cases the maximum range of motion ($2a$) was equal in the EW and NS directions, the average period being also practically identical in the two components.

In the storm (i)-(ii), the average period in Osaka was 7.0 and 7.5 sec. in the morning of the 22nd, being practically identical with the periods of 7.2 to 7.5 sec. observed in Tokyo and on the Asama-yama on the same day (Table III). With the close approach of the deep cyclone to, and the consequent intensification of the pulsatory oscillations in, Osaka, the average period there was in the night of the 22nd shortened to 5.8 to 6.0 sec.; while the period at the two other places above referred to became 7.7 to 8.0 sec., probably on account of the non-immediate proximity to the track of the storm centre. In the case (iii), the average period in Osaka was 5.9 to 6.2 sec., being not much different from the period of 6.2 to 6.3 sec. observed in Tokyo on the same occasion. These examples seem to point also to the identity in character of the pulsatory oscillations in Tokyo and in Osaka.

TABLE VI. AVERAGE PERIOD AND MAX. 2a OF THE LARGE
PULSATORY OSCILLATIONS OBSERVED IN OSAKA.
EW AND NS COMPONENTS.

EW Component.		NS Component.	
Average Period.	Max. 2a.	Average Period.	Max. 2a.
In the morning of Sept. 22nd, 1912.			
5.9sec.	0.130mm.	7.2sec.	0.130mm.
6.8	0.075	7.3	0.080
7.0	0.100	7.6	0.075
7.1	0.070	7.6	0.085
7.3	0.070	7.7	0.100
7.7	0.060		
In the night of Sept. 22nd, 1912.			
5.8sec.	0.180mm.	5.2sec.	0.205mm.
5.9	0.185	5.4	0.265
5.9	0.230	5.6	0.250
5.9	0.275	5.6	0.250
6.1	0.280	5.8	0.175
6.1	0.235	5.9	0.270
6.1	0.300	6.0	0.175
6.2	0.220	6.0	0.260
6.2	0.250	6.6	0.365
Jan. 22nd-23rd, 1913.			
5.1sec.	0.120mm.	5.5sec.	0.170mm.
5.8	0.145	5.8	0.145
5.8	0.120	6.1	0.125
5.9	0.170	6.2	0.100
6.0	0.080	6.4	0.160
6.1	0.130	6.4	0.145
6.1	0.145	6.5	0.125
6.1	0.070	6.5	0.110
6.2	0.095		

**TABLE VII. LARGE PULSATORY OSCILLATIONS ON
JAN. 22ND-23RD, 1913, TOKYO.**

Component.	Average. Period.	Max. 2a.	Instrument.
NS Component.	6.2sec.	0.36mm.	Hor. Pend., of natural oscillation period = 32sec., magnification=10.
	6.3	0.39	
	6.3	0.49	
	6.4	0.49	
EW Component.	6.0	0.38	<i>Do.</i> , of natural oscillation period = 32sec., magnifica- tion=30.
	6.0	0.40	
	6.0	0.50	
	6.1	0.30	
	6.2	0.38	
	6.3	0.45	
	6.4	0.45	
	6.4	0.33	
	6.6	0.28	
Vertical Component.	4.6	0.065	Natural oscillation period= 7 sec., magnification=20.
	5.3	0.17	
	5.3	0.15	
	5.7	0.15	
	5.9	0.15	
	6.4	0.20	
	7.1	0.22	

6. Pulsatory oscillations on Jan. 22nd-23rd, 1913, Tokyo.

The pulsatory oscillations observed in Tokyo on Jan. 22nd-23rd, 1913, were the greatest which occurred since Nov. 17th-18th, 1900, when the training ship Tsukishima Maru of the Nautical School was lost during the typhoon somewhere in the Suruga Bay. The depression centre of 748 mm, which had existed in the vicinity of Nagasaki at 10 p.m. on the 21st, passed along the S. coast of Shikoku, and, deeping to 742 mm, moved up at 2 p.m. on

the 22nd to the vicinity of Choshi at a distance of about 100 km from Tokyo, thence passing to the NE into the Pacific. During the night of the 22nd, the motion attained the maximum intensity, consisting of regular well-defined vibrations. As shown in Table VII, the max. 2a's in the EW, NS, and the vertical directions were respectively 0.50 mm, 0.49 mm, and 0.22 mm; the general mean periods in the first two of these component movements being 6.2 sec. and 6.3 sec., while the period in the third varied from about 5 sec. to about 7 sec. Figs. 3, 4, and 5 give the reproductions of parts of the diagrams as follows:—

Fig. 3. Record at Hongo, from a NS component Horizontal Pendulum of magnification=20, and of natural oscillation period=48.5 sec.

Fig. 4. Record at Hitotsubashi, from an EW component Horizontal Pendulum of magnification=20, and of natural oscillation period=30 sec.

Fig. 5. Record at Hongo, from a vertical motion seismograph of magnification=20, and of natural oscillation period=7 sec.

Fig. 2, which gives the resultant horizontal movements of the pulsatory oscillations on the days in question, is a part of the record furnished by a large duplex pendulum seismograph of the Gray-Ewing type recently set up in the "Earthquake-proof House" in the University ground, adapted to a continuous mechanical registration, of the following instrumental constants:—

Ordinary pendulum: Height=392 cm, Weight of the bob
=150 kg.

Inverted pendulum: Height=81 cm, Weight of the bob
=35 kg.

Pointer magnification=20

Natural oscillation period of the *steady system*=14 sec.

Rate of motion of the smoked paper=about $2\frac{1}{2}$ cm per minute.

The diagram shows in a very clear manner an incessant change in the azimuths of motion of the pulsatory oscillations, a fact which has been known since many years.*

7. On the nature and cause of pulsatory oscillations. It is known that the period of the well pronounced pulsatory oscillations at different places is included between about 4 sec. and about 8 sec. Now, from the results obtained in the foregoing §§, it can further be inferred that the period in question is on a given occasion practically identical at such mutually distant places as the Asamayama and the cities of Tokyo and Osaka, not only in the mean value, but also in its variation from day to day. As, however, the amplitude of motion was considerably smaller on the Asamayama than in Tokyo and Osaka, the question arises: Are the pulsatory oscillations on the volcano standing at the centre of the Island the transmissions of those originally generated in the soft soils of the extensive planes on which the two above mentioned cities are situated? A special fact to be remembered in answering this question is the insignificance of the pulsatory oscillations even on the hard and rocky ground situated close to, or directly on, the coast. Thus, the maximum limit of the EW component motion in the volcanic Island of Oshima** was invariably small, according to the temporal observations made in 1908; the maximum amount of 0.02 mm having there occurred on the occasion of a storm in the night of Aug. 7th. It appears likely that the pulsatory oscillations are produced in the rocky underlayers and magnified when transmitted to the soft soil forming the extensive alluvial and diluvial plains at different places.

Another peculiar feature of the pulsatory oscillations, which

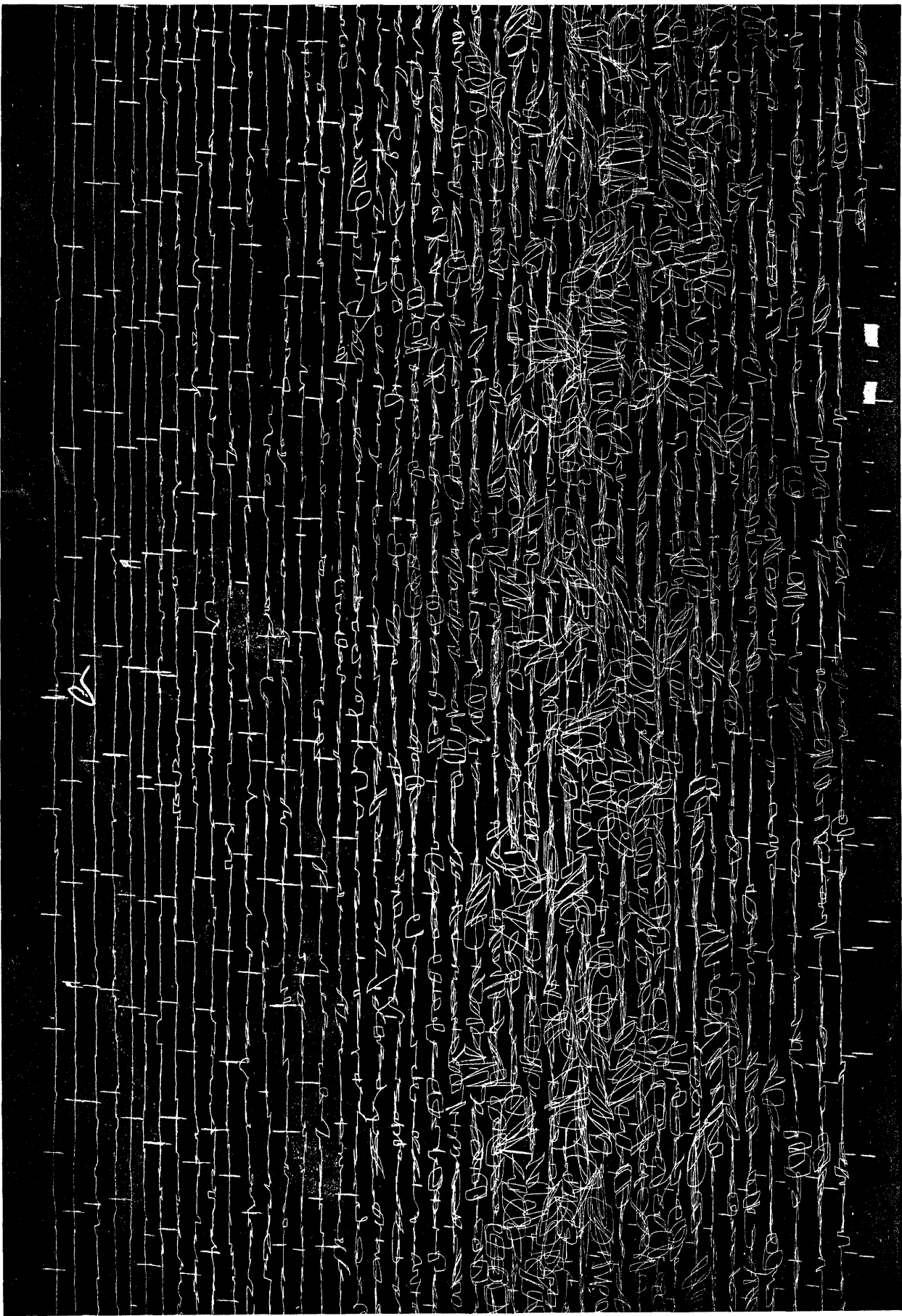
* The non-correspondence between the EW and NS horizontal components in the occurrence of the maximum groups has been pointed out by the present author in Jour. Sc. Coll., Tokyo Imp. Univ., Vol. XI, 1899. ** The *Bulletin*, Vol. III.

are individually equivalent to an earthquake vibration, is the non-correspondence or dissimilarity in the occurrence of the successive oscillations even at observatories of only a few miles mutual distance, for instance, at Hongo and Hitotsubashi in Tokyo; it being almost entirely impossible to identify the different maximum movements or groups from the simultaneous registrations at these two places, which show no difference in the period among themselves. This indicates that the pulsatory oscillations actually observed are not the results of a progressive disturbance as an earthquake, in which latter case the instrumental diagrams obtained at the two above mentioned stations are more or less similar to each other, at least with respect to the slow-period elements of the seismic motion. Other characteristics of pulsatory oscillations by which these are distinguished from the earthquake motion, are three-fold, as follows:— firstly, the equality of the max.2a's in the EW and the NS components; secondly, a constant change in the direction of the resultant horizontal oscillation; and, thirdly, a frequent preponderance of the vertical component movements. Taking together these facts into consideration, the pulsatory oscillations seem to be the results of the underground disturbances originating at an infinite number of points, due probably to the play of the volcanic activity or the internal pressure consequent to deep barometric depression or the existence of heavy ocean swells. In other words, the pulsatory oscillations are regarded as a succession of deep-rooted small earthquake disturbances, as is suggested by the occurrence of the volcanic tremors and pulsations observed at the Usu-san at the time of its eruption in 1910.*

* This Volume, No. 1.

Fig. 2. Duplex Pendulum Seismograph Record of the pulsatory Oscillations on Jan. 22nd-23rd, 1913, at Hongō, (Tokyo). Magnification = 20.

(End)



(Commencement)

Time-scale Interval = 1 minute.

Fig. 3. Pulsatory Oscillations on Jan. 22nd-23rd, 1913, observed at Hongo, (Tokyo). NS Component. Magnification=20.

(End)

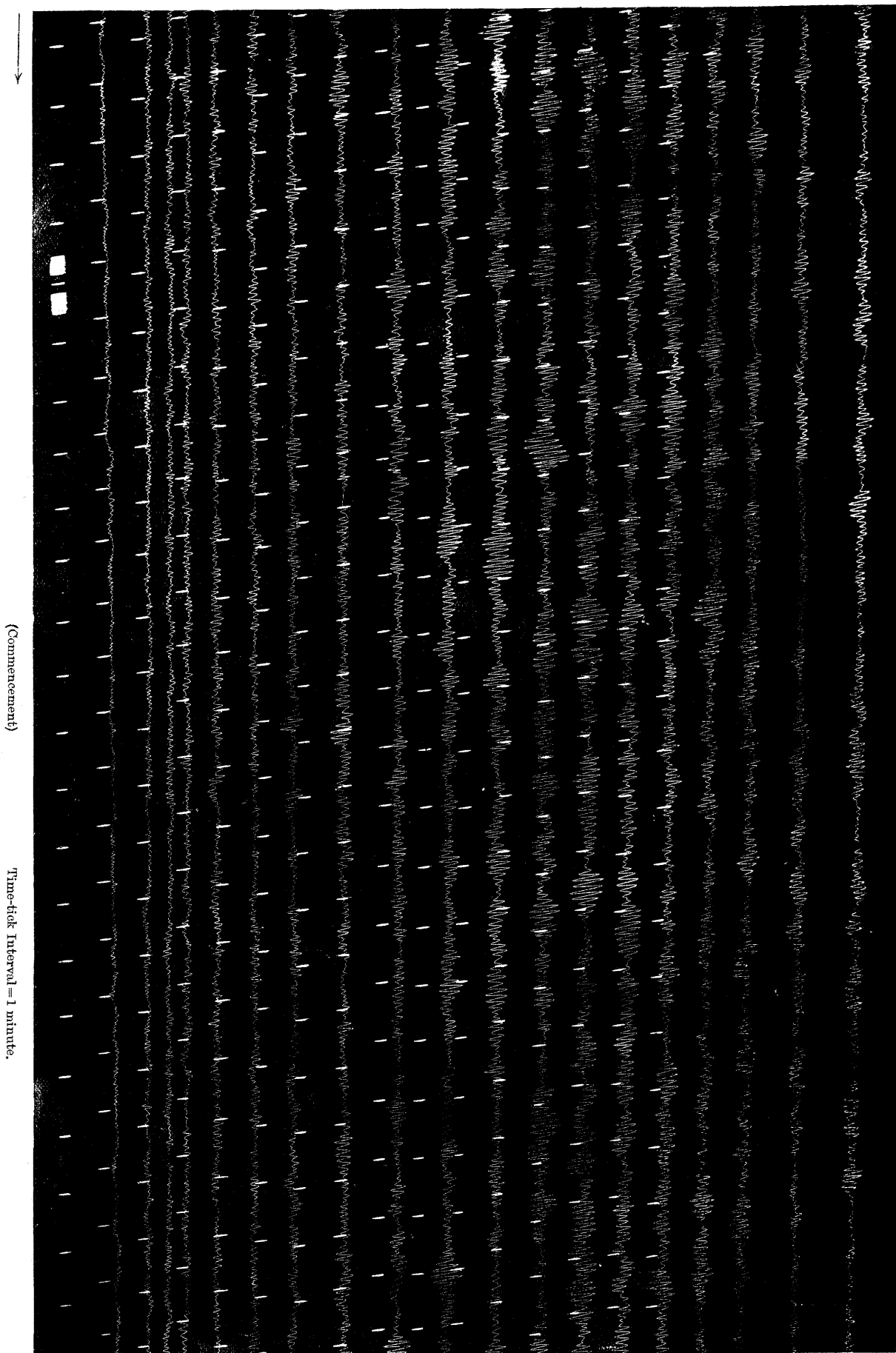
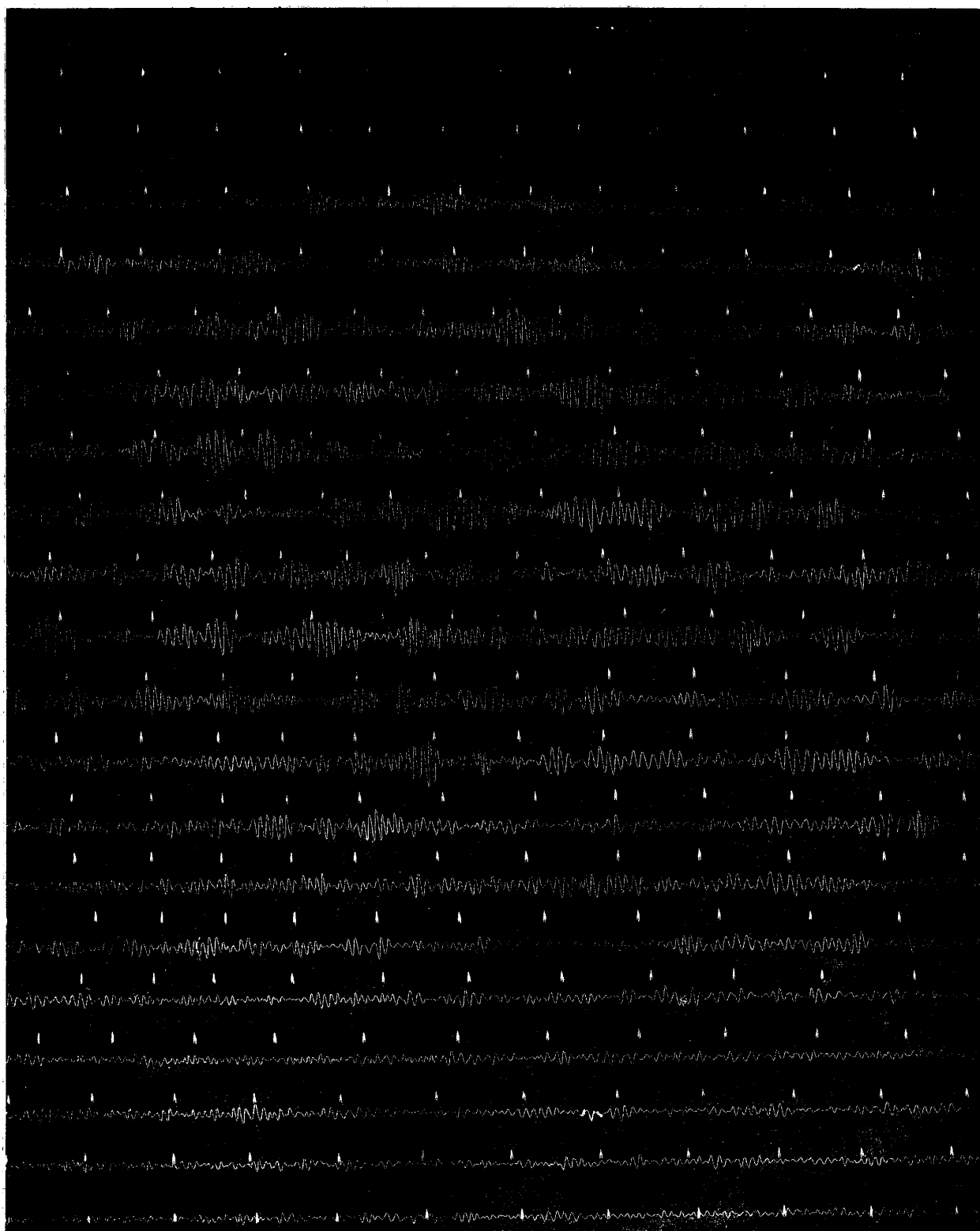


Fig. 4. Pulsatory Oscillations on Jan. 22nd-23rd, 1913, at Hitotsubashi (Tokyo).
EW Component.

(End)



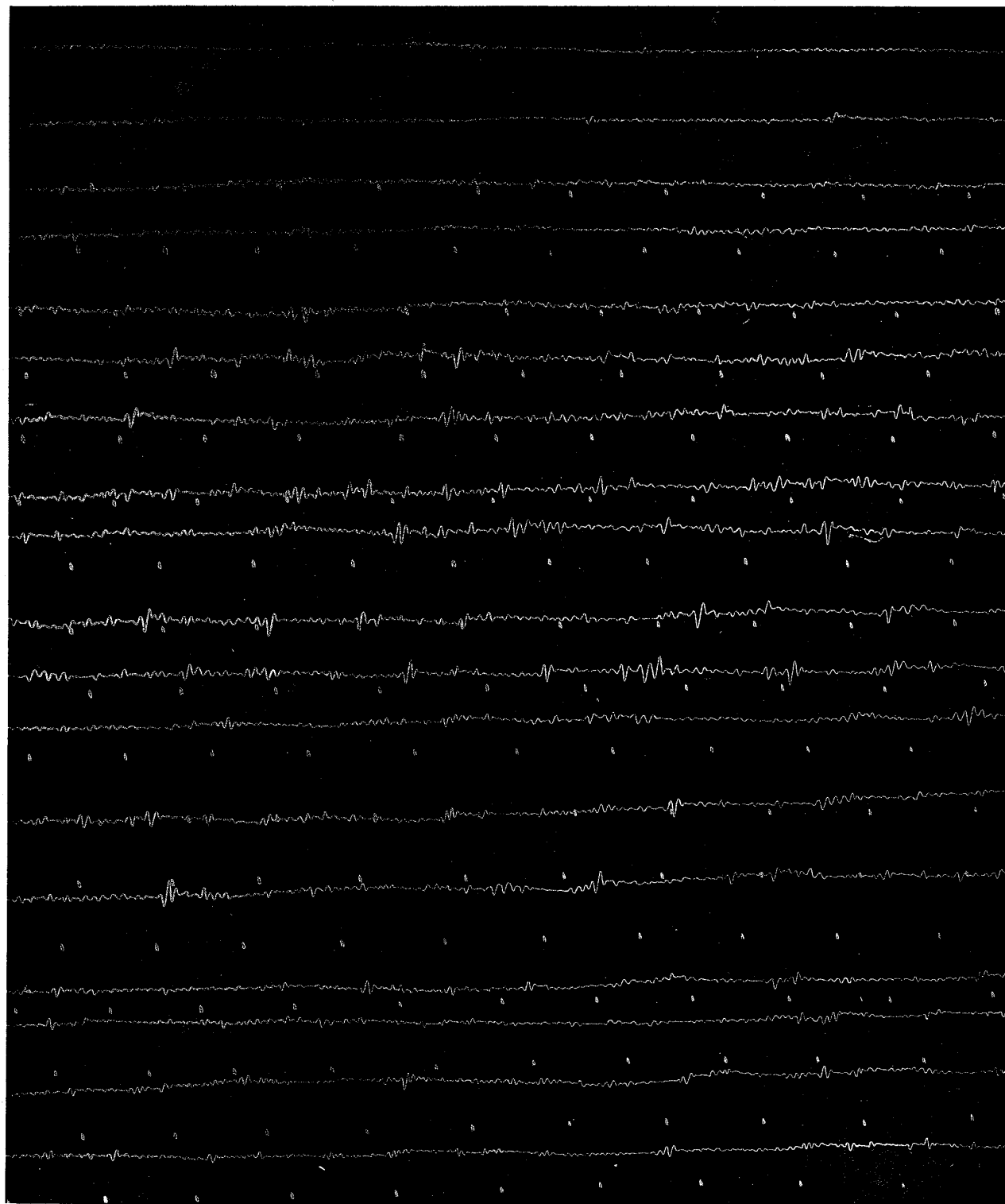
(Commencement)

Magnification = 20. Time-tick Interval = 1 minute.

Fig. 5. Pulsatory Oscillations on Jan. 22nd-23rd, 1913, observed at Hongo, (Tokyo).
Vertical Component.

Magnification=20. Time-tick Interval=1 minute.

(End)



→

(Commencement)