CHAPTER XII. TROMOMETER OBSERVATIONS IN TOKYO OF ASAMA-YAMA ERUPTIONS(THE ERUPTIONS AND EARTHQUAKES OF THE ASAMA-YAMA IV [Strong Asama-yama Outbursts, Dec. 1912 to May 1914])

journal or publication title	Bulletin of the Imperial Earthquake Investigation Committee
volume	7
number	1
page range	176-188
year	1914-08-23
URL	http://hdl.handle.net/2261/16057

CHAPTER XII. TROMOMETER OBSERVATIONS IN TOKYO OF ASAMA-YAMA ERUPTIONS.

112. The earth shakings caused by the strong Asama-yama eruptions, whether detonative or non-detonative, are clearly registered by the tromometers at the Seismological Institute in Tokyo, provided the pulsatory oscillations are not too large to confuse the earthquake motion. In the next two §§ I give the analysis of the EW component records from the 120-times tromometer, (magnified photographically to the resultant enlargement of about 1,000 times), of the following eight Asama-yama eruptions :—

(i)	Explosion of	May 31st,	1909;	11.25 p.m.
(ii)	„	May 8th,	1911;	3.27 „
(iii)	„	June 26th,	1913;	11.41 „
(iv).	„	July 13th,	„ ;	4.01 „
(v)	„	„ 19th,	„ ;	0.54 „
(vi)	„	Aug. 12th,	„ ;	11.20 „
(vii)	Non-detonative eruption of	Nov. 6th,	1913;	1.21 p.m.
(viii)	„ „ „	„ 20th,	„ ;	3.40 p.m.

The eruptions, (i) to (vi), were strong detonative explosions, while the two others, (vii) and (viii), were non-detonative outbursts.

113. ***Strong Asama-yama eruptions observed in Tokyo: EW component tromometer records.*** Explosions, (i) to (vi).

(i). *Explosion of May 31st, 1909, at 11.25 p.m.* Total duration=3 m 45 s. The motion, which was somewhat confused by the small pulsatory oscillations, was small for about 23.5 sec. The maximum phase lasted 55 sec. and began with two vibrations (2a=0.004 mm) of periods 5.6 and 4.2 sec. respectively. The next 5 vibrations (max. 2a=0.005 mm) with the T of 2.9 sec. lasted together 14.6 sec. The next 4 vibrations were smaller and lasted 8.5 sec.: T=2.1 sec. Then followed 2 slow vibrations of T=4.2

sec. During the next 14.1 sec., the vibrations were again a little quicker: T=3.1 sec. The *pulsatory oscillations* existing about the time of the earthquake motion had the T of 4.4 sec., with the max. 2a of 0.002 mm.

(ii) *Explosion of May 8th*, 1911, *at* 3.27 *p.m.* Total duration=7 m 27 s. For the 1st 24.3 sec.,* the motion was small, there being traces of slow vibrations of T=5.3 sec. [Maximum phase: duration=84 sec.] For the 1st 13.1 sec., there were three well defined vibrations of T=4.4 sec., the 2nd of which had the max. 2a of 0.0164 mm and occurred 31.2 sec. after the commencement of the earthquake. For the next 20.0 sec., the motion was small, the vibrations of T=1.9 sec. being mixed with slower ones. Then, 51.2 sec. from the commencement, took place two large slow vibrations of T=5.6 sec., 2a=0.0101 mm, lasting together 11.1 sec. During the next 12.0 sec. there were 4 vibrations, which were again a little quicker: T=3.0 sec., 2a=0.0097 mm. For the next 28.2 sec., the period was T=3.1 sec., the max. 2a being 0.0076 mm. Thereafter, the motion was much smaller. The *pulsatory oscillations* immediately before the earthquake indicated an average period of 3.1 sec. (max. 2a=0.0021 mm).

(iii) *Explosion of June 26th*, 1913, *at* 11.41 *p.m.* Total duration=5 m 58 s apprx. For the 1st 20.5 sec.,* the motion consisted of three slow vibrations of T=6.8 sec. and of gradually increasing amplitude. [Maximum phase: duration=50 sec.] The 1st $1\frac{1}{2}$ vibrations had the T of 3.7 sec., whose 1st displacement was directed eastwards, and whose 2nd had the max. 2a of 0.0193 mm. For the next 23.7 sec., the motion was smaller, being composed of about 9 vibrations of T=2.6 sec., max. 2a=0.0093 mm. For the next 20.5 sec., the motion became again larger, being

* The commencement is obscure, on account of the presence of pulsatory oscillations.

composed of 4 vibrations of T=3.8 sec., max. 2a=0.0147 mm, and 2 smaller ones of T=2.7 sec. The subsequent motion was principally composed of vibrations of T=3.7 sec. The *pulsatory oscillations* preceding and following the earthquake motion in question also indicated, amongst the others, the periods of 3.7 and 2.7 sec., the max. 2a being 0.0039 mm. The average period of the *micro-tremors* was about 0.6 sec.

(iv) *Explosion of July 13th*, 1913, *at* 4.01 *p.m.* Total duration= 6^m 25^s apprx. For the 1st 12.1 sec., the motion was small: T= 2.3 sec. For the next 17.5 sec., there were 3 slow vibrations of T=6.7 sec. and of increasing amplitude. [Maximum phase: duration=45 sec.] For the 1st 5.6 sec., there took place 1½ large vibrations of T=3.7 sec., and 2a=0.0156 mm. For the next 20.1 sec., the motion consisted of 9 small and nearly equal vibrations of T=2.2 sec. (max. 2a=0.0084 mm), grouped into those of double length. For the next 19.0 sec., the motion became again large and comprised 6 vibrations of T=3.2 sec., max. 2a=0.0124 mm. In the subsequent portion, the vibrations were smaller and had the T of 3.3 sec., grouped into those of period of double length.

(v) *Explosion of July* 19*th*, 1913, *at* 0.54 *p.m.* Total duration $=7^m$ 35^s apprx. For the 1st 31.1 sec., the vibrations were small. [Maximum phase: duration=51 sec.] First there took place 1½ vibrations of T=4.6 sec., 2a=0.026 mm. For the next 22.3 sec., there were 9 quicker and smaller vibrations of T=2.5 sec., 2a= 0.0143 mm. For the next 21.9 sec., the motion became again active, there being 4 large vibrations (2a=0.0141 mm) of T=3.8 sec., and 2 small ones (2a=0.0099 mm) of T=3.3 sec. Thereafter the vibrations were small: 2a = 0.008 mm, T = 3.3 sec., T =26 sec. The period of the *pulsatory oscillations*, which occurred immediately before the earthquake, were 3.3 and 2.6 sec., (max. 2a=

0.0057 mm). The period of the *micro-tremors* was 0.61 sec.

(vi) *Explosion of Aug. 12th,* 1913, *at* 11.20 *p.m.* Total duration$=7^m$ apprx. During the 1st 31.9 sec., there were traces of the vibrations of T=6.2 sec., 4.4 sec., and 3.3 sec. [Maximum phase: duration=50 sec.] The motion began with 3 displacements, which lasted 7.6 sec., and the 1st two of which formed the max. vibrations of T=5.2 sec., 2a=0.0275 mm. For the next 23.1 sec., the motion was small, (max. 2a=0.0114 mm), comprising 10 vibrations of different periods. Then there took place two large vibrations of T=3.8 sec., 2a=0.0242 mm, lasting together 7.5 sec. During the next 11.9 sec., there were 4 vibrations of T=3.0 sec., 2a=0.0145 mm. In the subsequent portion, the motion was smaller: T=3.3 sec., max. 2a=0.0104 mm. The well-defined *pulsatory oscillations,* which occurred before and after the earthquake motion, indicated an average period of 4.1 sec., with the max. 2a of 0.0088 mm.

114. *Non-detonative eruptions registered in Tokyo.*

(vii) *Eruption of Nov. 6th,* 1913, *at* 1.21 *p.m.* Tromometer Diagram; EW Component. Total duration$=6^m\ 14^s$. The time interval between the commencement of the preliminary tremor and the beginning of the maximum phase was 31.3 sec. [Principal portion: duration=66.0 sec.] The motion was unusually large, and during the 1st 9.7 sec., there were 1½ vibrations of T=6.5 sec., 2a=0.024 mm. During the next 11.0 sec., there were 2 nearly equal vibrations of slightly shorter period: T=5.5 sec., 2a=0.027 mm. Then followed 6 quicker vibrations of decreasing magnitude and of T=2.9 sec., which together lasted 17.4 sec., and the 1st of which had the max. (absolute) 2a of 0.031 mm. Then, for the next 15.2 sec., there were again 2 slow vibrations of T=7.6 sec., 2a=0.019 mm, with some superposition of small movements. During the remaining 13.6 sec. of the principal portion, there were $4\frac{1}{2}$ quick vibrations of T=3.0 sec., 2a=0.025 mm. [End portion.] During the 1st 56.7 sec., the motion was nearly constant in amplitude and was composed of slow vibrations of T =5.7 sec., 2a=0.014 mm, with the superposition of some quicker movements. Thereafter the motion was much smaller, the principal period being about 3.6 sec. The period of the principal *pulsatory oscillations*, which existed before and after the earthquake motion was about 5.0 sec.

(viii.) *Eruption of Nov. 20th*, 1913, *at* 3. 40 *p.m.* Tromometer Diagrams: EW, NS, and Vertical Components. Total duration=7^m apprx. The motion due to this eruption was unusually large, but the preliminary and end portions were confused by the presence of pulsatory oscillations.

EW Component. The maximum phase, which lasted 74.2 sec., began with three vibrations of T=5.3 sec., followed by three others of T=3.7 sec. Then took place six vibrations of T=2.7 sec., the 1st three of which were large (max. 2a=0.022 mm). The two next vibrations were slow (T=7.0 sec.) and mixed with smaller ones. Then followed again five quicker movements of T=3.1 sec., max. 2a=0.025 mm. The principal *pulsatory oscillations* (max. 2a= 0.009 mm) had the T of 6.7 sec., and were mixed with small vibrations of T=2.7 sec. There were cases where the pulsatory oscillations consisted of regular movements of T=3.6 sec.

NS Component. The most active portion, 37.3 sec. in duration, was composed of the vibrations of T=3.0 sec., max. 2a= 0.021 mm.

Vertical Component. The motion was distinctly indicated for 70 sec., and consisted of the vibrations of T=3.0 sec., max. 2a= 0.02 mm.

115. *Remarks on Tokyo registrations of Asama-yama eruptions.* The diagrams of the different Asama-yama eruptions obtained in Tokyo are mutually similar, almost vibration for vibration. The ordinary preliminary tremor and the earlier portion of the principal portion are generally not well pronounced in the cases under consideration, while the maximum motion phase is always distinctly indicated. Thus, the duration of the preliminary portion, i.e., the preliminary tremor and the earlier stage of the principal portion preceding the maximum phase, varied, in the four well-defined cases, between 29.6 and 31.9 sec., giving the average value of 31.0 sec. The maximum phase lasted from 45 to 84.4 sec., with the average interval of 59.4 sec.; while the average total duration of the earthquake motion was about 7^m.

TABLE XXVIII. TOKYO OBSERVATIONS: DURATIONS OF THE DIFFERENT PHASES OF MOTION.

Preliminary Portion.	Maximum Phase.	Total Earthquake.
29.6 sec.	45 sec.	6 min. 00* sec.
31.1	50	6 14
31.3	50	6 25*
31.9	51	7 00*
	55	7 00*
	66	7 27
	74.2	7 35*
	84.4	
31.0	**59.5**	——

* Only approximate. Mean values are printed in thick figures.

It will be noticed that the total duration and the duration of the maximum phase in Tokyo of the Asama-yama eruptions, being in the mean respectively about 7 min. and 1 min., are much longer than the total duration and the duration of the specially strong part of the disturbances observed on the mountain itself (Yuno-taira), where the mean values of the duration in question were 118 and 15 sec.

The mean periods of vibrations (Table XXIX) in the different phases of the earthquake motion, compared with those of the pulsatory oscillations existing immediately before or after the latter, were as follows :—

Phase of Motion.		Period.	
Earthquake (Eruption)	Preliminary portion ..	6.0 sec.	2.8 sec.
	Maximum phase	5.5	3.0
	End portion	—	3.3
Pulsatory Oscillation		5.1	3.1
Mean		**5.5**	**3.1**

Thus the two groups of periods, whose mean values are respectively 5.5 and 3.1 sec., were found in the earthquake vibrations caused by the Asama-yama eruptions as well as in the pulsatory oscillations. In other words, the seismic movements in question are nothing else than the magnifications of the natural vibrations of the ground, just as the "tsunami", or destructive sea-waves, consist in the amplification of the water oscillations existing more or less at all times.

TABLE XXIX. TOKYO OBSERVATIONS: PERIODS OF VIBRATION OF THE EARTHQUAKES DUE TO THE ASAMA-YAMA ERUPTIONS COMPARED WITH THOSE OF THE PULSATORY OSCILLATIONS.*

Asama-yama Earthquakes.				Pulsatory Oscillations.
Preliminary Tremor.	Principal Portion.		End Portion.	
sec. (mm.)	sec. (mm)	sec. (mm.)	sec. (mm.)	sec. (mm.)
6.8	7.6 (0.019)	3.8 (0.0147)	5.7 (0.014)	6.7
6.7	7.0	3.8 (0.0141)		5.0
6.5 (0.024)	6.5 (0.024)	3.8 (0.0242)		4.4 (0.0025)
6.2	5.6 (0.010)	3.7 (0.0193)	3.7	4.1 (0.0088)
5.3	5.6 (0.004)	3.7	3.3	**5.1**
4.4	5.5 (0.027)	3.7 (0.0156)	3.3 (0.008)	
6.0	5.3	3.3 (0.0100)	3.3 (0.010)	3.7 (0.0039)
	5.2 (0.0275)	3.2 (0.0124)	2.6 (0.008)	3.6
3.3	4.6 (0.026)	3.1	**3.2**	3.3 (0.0057)
2.3	4.4 (0.0164)	3.1 (0.0250)		3.1 (0.0021)
2.8	4.2	3.1 (0.0076)		2.7 (0.0039)
	4.2	3.0 (0.0145)		2.7
	5.5	3.0 (0.010)		2.6 (0.0057)
		3.0 (0.025)		**3.1**
		2.9 (0.031)		
		2.9 (0.005)		
		2.7		
		2.7 (0.022)		
		2.6 (0.0093)		
		2.5 (0.0143)		
		2.2 (0.0084)		
		2.1		
		1.9		
		3.0		

* Mean values are printed in thick figures. 2a corresponding to a given period is enclosed within brackets.

The values of the max. 2a in the EW component of the different eruptions are given below:

Eruption.		Max. 2a. (in Tokyo)	2nd Displacement of the Initial Vibration. (Yuno-taira.)
(i)	May 31st, 1909.	0.005 mm	mm —
(ii)	May 8th, 1911,	0.0164	—
(iii)	June 26th, 1913. (11 p.m.)	0.0193	0.093
(iv)	July 13th, ,,	0.0156	0.123
(v)	,, 19th, ,,	0.026	0.127
(vi)	Aug. 12th, ,, (11 p.m.)	0.0275	0.217
(vii)	Nov. 6th, ,,	0.031	—
(viii)	,, 20th, ,,	0.025	0.019 (Asama Pasture Ground.)

From the above list it will be observed that the strong eruption of Aug. 12th, 1913, whose "initial vibration" was large, indicated also a comparatively large motion in Tokyo; while the non-detonative eruptions on Nov. 6th and 20th, 1913, with or without the "initial vibration," caused a large amount of motion in the latter. Again, the explosion of May 8th, 1911, whose sound area was quite extensive, was propagated, in a very insignificant seismic manner. It is likely that the greatest earthquake motion is produced by the long-continued eruptions, which, with little accompanyment of the surface phenomena of a loud detonation, gives out a considerable amount of the smokes and ashes.

116. ***Time of occurrence in Tokyo.*** In the following table I give a comparison of the time (t_0) of commencement, at the Yuno-taira observatory on the Asama-yama, of the earthquake motion caused by the different strong eruptions and the time (t_m)

of appearance at the Seismological Institute, in Tokyo, of the maximum phase of motion due to the same cause of disturbance, with the value of the time difference $\delta t_m = t_m - t_0$; the time determinations in question having been made with a great accuracy.

Eruption.	t_0 {Yuno-taira, on Asama-yama.}	t_m {Maximum Phase in Tokyo.}	$\delta t_m = t_m - t_0$.
	h m s	h m s	m s
June 26th.	11 41 59 p.m.	11 43 13 p.m.	1 14
July 13th.	4 01 19 p.m.	4 02 36 p.m.	1 17
„ 18th.	2 08 25 a.m.	2 09 36 a.m.	1 11
„ 19th.	0 54 03 p.m.	0 55 16 p.m.	1 13
Aug. 12th.	11 20 33 p.m.	11 21 46 p.m.	1 13
Mean.	———	———	1 13.6

According to the above table, the difference between the time of the earthquake commencement at Yuno-taira and that of the maximum phase in Tokyo varied in the five cases between $1^m\ 11^s$ and $1^m\ 17^s$, giving the mean value of $\delta t_m = 1^m\ 13.^s6$.

As the duration in Tokyo of the preliminary tremor and the earlier part of the principal portion preceding the maximum phase is 31.0 sec., it follows that the interval between the time of the first occurrence of the earthquake motion at Yuno-taira and that at Tokyo Seismological Institute is $\delta t_0 = 1^m\ 13.^s6 - 31.^s0 = 42.^s6$.

117. ***"Sound shock" observed in Tokyo.*** In those cases, in which the detonations of the Asama-yama explosions were perceived in Tokyo, the arrival of the sound waves was marked on the tromometer diagrams by the appearance of the "sound shock," or a disturbance consisting of a series of extremely minute quick tremors a definite time interval after the earthquake occurrence. I describe in this § the EW component tromometer records of the "sound shocks" photographically enlarged to the resultant magnification of 1,000 to 3,000 times, obtained on the occasions of the following three explosions: (i), Dec. 7th, 1909; (ii), May 8th, 1911; and (iii), Aug. 12th, 1913. There were several other cases in which the sound shock was confused by the existence of conspicuous pulsatory oscillations. The illustrative diagrams are given in Figs. 68 and 69.

The position of the Seismological Institute is as follows:

$\varphi=35° 42' 40''$ N; $\lambda=139° 45' 48''$ E.[1]

Radial Distance from the Asama-yama=135.40 km.[2]

(i) *Explosion of Dec. 7th*, 1909. (Fig. 67.) Total duration of the "sound shock" =45 sec. For the 1st 6.6 sec., the motion was small: T=0.44 sec., max. 2a=0.0015 mm. Then began the principal portion, and for the next 20.0 sec., the vibrations were active and had the period of 0.40 sec., the greatest 2a of 0.0105 mm having occurred 16.6 sec. from the commencement of the "sound shock". The subsequent motion was very small, the period being 0.40 sec. The arrival of the detonation or audible sound shock probably coincided with the commencement of the principal portion.

(ii) *Explosion of May 8th*, 1911: Tromometer EW Component Diagram. (See Fig. 69.) Total duration of the "sound shock" =44 sec. The preliminary portion, whose commencement was not well marked on account of the presence of pulsatory oscillations and micro-tremors, lasted about 12.5 sec., consisting of quick small movements of T=0.42 sec. Then at 3.34.38 p.m. the motion became suddenly large, denoting probably the moment of arrival of the detonation. The vibrations remained active for

(1) Measured from the War Department Map of 1: 10,000 scale.

(2) The position of the Asama-yama crater taken from the 1:200,000 scale map of the Imperial Geological Survey being $\varphi=36° 24' 30''$ N, $\lambda=138° 32'$ E.

the next 11.2 sec., with the average T of 0.40 sec.; the max. 2a of 0.0076 mm occurring at the commencement of this phase. The subsequent vibrations were much smaller, the period being 0.42 sec. The pulsatory oscillations at the time of the disturbance had the period of 3.3 sec., with the max. 2a of 0.0038 mm.

As noted in the *Bulletin*, Vol. VI, p. 87, the detonation, which was perceived by the present author at the Seismological Institute, was made up of loud rushing sounds, commencing at $3^h 34^m 37^s$ p.m. and lasting about 10 sec., during which interval the windows were shaken considerably as by strong winds or by an earthquake of moderate intensity.

(iii) *Explosion of Aug. 12th, 1913, at 11. 20 p.m.* The "sound shock", whose total duration was only about 23 sec., was very slight, its first indication being at $t_s = 11^h\ 27^m\ 05^s.7$ p.m. 1.3 sec. later on, namely, at $11^h\ 27^m\ 07^s$ p.m., the motion became larger (max. 2a=0.0036 mm), corresponding to the arrival of the audible sound waves. The duration of the principal portion was about 2.5 sec. At the Seismological Institute, the time of commencement of the maximum phase in the EW component diagrams was at $t_m' = 11^h\ 21^m\ 45.^s5$ p.m.; that of the earthquake commencement being, therefore, $t_1 = 11^h\ 21^m\ 14.^s5$ p.m. The time difference between the arrivals of the earthquake motion and the sound wave in Tokyo (Seismological Institute) is thus $= t_s - t_1 = 5^m\ 31^s$.

The present author, who was at the time writing by a desk with a pocket chronometer before him, in his house (Seki-guchi-daimachi, Koishikawa District), heard the sound of the eruption in question, which was like that caused by the fall of a heavy weight on the ground and was less than 1 sec. in duration, the doors and *shoji* being slightly shaken. The time of the arrival of the sound was $11^h\ 26^m\ 58^s$ p.m., the place of observation

($\varphi = 35° 42' 40''.5$ N; $\lambda = 139° 43' 32''.8$ E) being at the radial distance of 132.08^{km} from the Asama-yama. Thus the differences of the radial distances of, and of the times of arrival of the detonation at, the Seismological Institute and my house were respectively $135.40 - 132.08 = 3.32$ km, and $11^h\,27^m\,07^s - 11^h\,26^m\,58^s = 9$ sec., being mutually at a fair agreement.

In the three cases considered above, the values of the total duration were respectively 23 sec., 44 sec., and 45 sec.; while those of the principal portion were respectively 2.5 sec., 11.2 sec., and 20 sec. The principal vibration period varied between 0.40 and 0.44 sec., with the mean of 0.41 sec., the greatest value of the EW component max. 2a being 0.0105 mm.

The "sound shock", which appears on the tromometer diagrams in Tokyo only when the detonation is heard in the latter, seems to consist, not in the elastic shakings of the writing pointer of the tromometer under the influence of the air disturbances, but in the real movements of the ground due probably to the impact, or the change in the barometric pressure attending the propagation, of the explosive waves. The noon-gun of Tokyo, fired at a distance of 3 km from the Seismological Institute, is sometimes audibly very loud, giving, however, no "sound shock" record on the smoked paper. Again, the peals of thunders produce, even when very strong, no effects of the kind. It thus seems likely that the amount of energy involved in the sound waves of a strong Asama-yama explosion must be comparatively great, and capable of imparting minute tremors to the ground, as they radiate out. In the case of the explosion of Oct. 15th, 1913, registered at the Asama Pasture Ground, the "sound shock" generated in the transverse component the greatest vibration with the period characteristic to the place of observation.