the eruption in 1669 and that on Feb. 5th, 1704. Then followed a period of the activity of 29 years, including 16 eruptions, the last of which occurred on July 30th, 1733. Thereafter the Asama-yama became again unusually quiet, there being, in the course of the next 50 years ending with the 3rd year of the Temmei period (1783), only two explosions in 1754, one in 1776, and a few in 1777, which were all small. Especially, during the 2 or 3 years immediately preceding the terrible Temmei disaster, the smoke had entirely ceased to be issued from the crater, whose bottom had gradually been raised up almost to the level with the mountain top itself. It will thus be observed that the Temmei eruption was the result of the outburst of the volcanic energy accumulated during the course of long years; the crater bottom, raised up by means of the powerful underground explosive force, having kept the stress till the last stage. Moreover, as the crater was extremely shallow, an immense mass of molten and burning rocks and mud was finally ejected out of it, causing the dreadful volcanic avalanch.

CHAPTER IX. SEISMOGRAPHICAL OBSERVATIONS AT ASHINO-TAIRA ON THE ASAMA-YAMA.

54. *Object of the seismographical observations.* The tromometer observations made during the Usu-san eruption in July-August, 1910, at the immediate vicinity of one of the most active of the newly formed craterlets, indicated the existence, besides numerous small earthquakes, of the micro-tremors, or those minute quick movements of the ground whose period was about 0.5 sec.* The interesting features of this latter sort of motion are that the

* The *Bulletin*, Vol. V, No. 1.

tremors were in nature identical with the local earthquakes themselves and sometimes occurred to a marked degree when the different craterlets were quiet. These results, coupled with the fact that eruptions are often preceded by numerous earthquakes and detonations, indicate the possibility of prediction, at least, of certain class of these terrible convulsions of nature, through the observation of the premonitary phenomena, as was actually demonstrated by the recent Usu-san outburst. It is hereby to be noted that a complete observation of volcanic earthquakes and tremors can only be made at the immediate vicinity of the source of disturbance. Thus in the case of the Usu-san, the micro-tremors, which were very active at a radial distance of about 1 km, became almost perfectly evernescent when the distance was increased to 10 km. Apart from the question of prediction of eruptions, the seismographical study on active volcanoes constitutes an interesting branch of geophysical researchs, which has been so long neglected.

To institute the instrumental observation on the Asama-yama, which presents, on account of its recent activity, a tempting field for seismologists, a trial experiment was made at Yuno-taira with a portable 100-times horizontal tromometer, during two weeks from Sept. 21st to Oct. 3rd, 1910. Unfortunately the volcano was during that time perfectly inactive, and gave rise to no outburst, earthquake, or detonation, the consequence being that the instrument registered no local disturbance whatever. On Dec. 2nd of the same year, however, the Asama-yama made a strong explosion, followed by several minor ones. This caused me to repeat the experiment, at Ashino-taira, for nearly two months from Jan. 9th to March 5th, 1911. It would have been better to make the observation at Yuno-taira, which is higher than Ashino-taira by

about 574 metres vertical difference. But we were prevented from making any prolonged stay at the former place, on account of heavy snow falls and severe cold.* In the following § § are described the results of the Ashino-taira observations, in which we were able to record numerous earthquakes of the volcanic origin.

55. *Instruments.* The building utilized as a temporary observatory was a small solitary one-storied wooden house, covering about 50 sq. metres, which in summer time served as a sort of inn; the ground being hard and consisting of rock fragments mixed with red soil. The instrument, the same as that used at the Usu-san, was a portable tromometer, consisting of a pair of horizontal pendulums, each of which had a heavy mass of about 15 kg. and was adjusted to a proper oscillation period of 4.2 sec. The rate of motion of the smoked paper wrapped round the recording drum was about 25 mm per minute, and the writing pointer of each of the horizontal pendulums magnified the earthquake motion 100 times. The instrument was set up directly on the ground, with a proper stone foundation.

The orientation of the instrument was such that the two horizontal pendulums registered the *horizontal* movements respectively parallel and normal to the direction connecting the place of observation and the central axis of the mountain, namely, the *apparent* longitudinal and transverse components of the volcanic earthquake motion, provided the source of disturbance be situated under the crater, a supposition which is, in the instance in question, probably not very far out of the truth. The measurement was, in the present trial, limited to the horizontal motion, as the verti-

* In the summer of 1911, the work of seismographical registration was carried on at Yunotaira during nearly 4 months between June 25th and Oct. 20th.

cal motion had been found, in the case of the Usu-san observation, to be comparatively small.

56. *Daily weather notes.* The following list gives for the interval Jan. 7th and March 5th, 1911, the weather conditions at Ashino-taira, with some indications of the earthquakes and explosions, as noted daily by the observers Mr. T. Kato and Mr. C. Koborinai.

JANUARY, 1911.

7th. Clear.

8th. *Do.*

9th. *Do.* The Seismographical observation was commenced at 2½ pm.

10th. Cloudy; Snow-fall from 7 to 12 pm.

11th. Clear; Strong wind.

12th. Cloudy in the morning, strong rain from 10 am, heavy snow-fall from 1 pm, and snow storm during the night.

13th. Fair.

14th. Clear throughout the day. A slight sensible shock at 6.50 am, accompanied by no explosion.

15th. Cloudy in the morning, clear in the afternoon. An unfelt slight shock at 6.04 am.

16th. Snow storm from 0 am till the evening. At 11.20 pm, an explosion which emitted dense black smokes, accompanied by a detonation like the discharge of a gun.

17th. Cloudy in the morning, clear in the afternoon; strong wind prevailed throughout the day. At 2.54 pm, there was a slight sensible shock, not accompanied by explosion.

18th. Covered by light clouds during the morning, fair in the afternoon. There were 3 explosions, throwing out black smokes and fire sparks.

19th. Cloudy in the morning, snow falling from about the noon till the night. There were 4 explosions, which threw out black smokes, that at 9.47 am being attended by fire sparks. At 3.32 pm, a sensible shock. At 10.02 pm, a detonation like distant thunder.

20th. Snowy in the morning; fair in the night, followed by thick mist.

21st. Fair in the morning; covered by thin clouds in the night. There was an explosion at 0.16 pm, the black smoke ascending and expanding like an open umbrella. At 4.20 pm, an explosion of black smoke, not attended by an indication of movements on the seismogram. At 7.13 pm, a detonation like that of distant thunder, followed by two others a few minutes later on.

22nd. Frequent snow falls from the early morning, becoming fair in the night. A detonation at 6.57 pm.

23rd. Frequent snow falls from the early morning, becoming clear in the night. Strong

wind throughout the day. A detonation at 0.02 pm, two unfelt small shocks at 0.29 and 7.20 pm.

24th. Clear, some cirrus appearing in the afternoon; covered by strutus in the night. At 0.22 am, an unfelt shock. At 10.22 am, an explosion, whose smoke could not be observed on account of the strong winds prevailing on the mountain top.

25th. Clear, with some cirrus.

26th. Cloudy in the morning, clear in the afternoon. At 11.21 am, an explosion threw out black smokes.

27th. Misty in the morning; covered entirely by cirrus in the afternoon.

28th. Snow-fall, which became stormy after the evening and ceased at the midnight.

29th. Clear.

30th. Clear in the morning; covered by thin clouds in the afternoon at 9.38 am, a detonation like distant thunder, which, although accompanied at Ashino-taira by no shaking effect, caused at Iwamurata, a town situated at the S. base of the volcano, considerable rattlings of windows and doors.

31st. Cloudy in the morning; slightly rainy from 3.40 to 9.20 pm.

FEBRUARY, 1911.

1st. Cloudy, with cirrus.

2nd. Fair, with some cirrus. at 8.13 pm, a slight sensible shock with sound, not accompanied by an explosion.

3rd. Fair. Strong wind prevailed throughout the day.

4th. Clear. *Do.*

5th. Strong wind continued to blow; some cirrus appeared.

6th. Alternately fair and cloudy; snowy in the night. Strong wind throughout the day.

7th. Clear, with strong wind as before. At 0.04 am, a sound. At 0.52 am, a small unfelt shock.

8th. Clear during the day time; great snow storm in the night. At 5.22 am, a shock accompanied by sound.

9th. Great snow storm continued till 8 pm.

10th. Clear.

11th. Cloudy during the day time, fair in the night.

12th. Clear, strongly windy. A sound at 11.19.54 am.

13th. Clear in the morning, cloudy from noon, and fair from 4 pm. The wind ceased at 5 am.

14th. Fair and slightly windy in the morning, cloudy and windy in the afternoon, rainy from 5 pm, becoming stormy in the night. A sound at 4.08.42 pm.

15th. Fair and strongly windy; cloudy in the afternoon.

16th. Cloudy and strongly windy, with some snow.

17th. Cloudy at first, fair after 11 am.

18th. Cloudy, becoming fair at 7 pm, strongly windy till the evening.

19th. Snow-fall from 0 to 10 am, with occasional strong winds. A small insensible shock at 11.31.36 am; and a moderately strong shock at 11.41.42 am, not accompanied by sound. The seismograph registered altogether 6 earthquakes, between 11.18 am and 0.21 pm.

20th. Clear and calm, only small amount of white smoke escaping from the crater.

21st. Fair, becoming calm in the afternoon.

22nd. Fair and calm. A detonation at 10.22.50 am; sounds like distant thunders at 1.28.56 and 1.29.04 pm; and a slight sensible shock at 11.47.04 pm, (probably) not accompanied by sound.

23rd. Strong wind from 0 to 10 am; calm from 1 pm.

24th. Snow-fall from 2 am. A detonation at 9.37.03 am.

25th. Cloudy, the accumulation of snow since the previous day amounting to 25 cm.

26th. Fair, subsequently cloudy and a little windy.

27th. Fair.

28th. *Do.*

MARCH, 1911.

1st. Fair, subsequently cloudy and windy; rainy and snowy from 6 pm.

2nd. Fair, with westerly wind.

3rd. Fair and strongly windy, followed by snow-fall.

4th. Fair and strongly windy.

5th. Fair.

57. *List of Earthquakes.* I give below a list of the 39 volcanic earthquakes and sounds instrumentally observed at Ashino-taira, with the indication of the time of occurrence, the duration of the preliminary tremor, the total duration, and the maximum range of motion; the table not including those shocks, which were registered at Ashino-taira but which did not originate from the Asama-yama, except Nos. 28′ and 28″ whose origins lay at the base of the mountain and near the town of Ueda. The earthquakes which accompanied the actual explosions of the volcano are marked with asterisks(*).

TABLE XXX. ASAMA-YAMA EARTHQUAKES OBSERVED AT ASHINO-TAIRA ON THE WESTERN SLOPE OF THE VOLCANO. JANUARY 9TH—FEBRUARY 28TH, 1911.

No.	Date. (1911)	Time of Occurrence.	Duration of Preliminary Tremor.	Total Duration.	Maximum Motion.		Remarks.
					Longitudinal Component.	Transverse Component.	
	Jan.	h m s	s	m s	mm	mm	
1	11	1 39 53 am.	0.0	0 13	0.008	0.010	Unfelt.
2	14	6 50 24 „	1.5	0 34	0.06	0.05	Sensible.
3	15	6 04 32 „	1.6	0 16	0.023	0.015	Unfelt; quick in character.
4*	17	2 04 27 „	2.4	2 14	0.175	0.045	Accompanied by a loud detonation and ejection of black smoke.
5	„	2 54 00 pm.	1.2	0 29	0.038	0.038	Sensible.
6*	18	1 08 19 „	1.3	1 00	0.060	0.045	Accompanied by ejection of black smoke.
7*	„	5 21 00 „	—	1 00	0.026	0.020	*Do.*
8*	„	9 27 51 „	—	1 00	0.070	0.050	*Do.*
9*	19	1 15 20 am.	—	1 30	0.123	0.075	*Do.*
10*	„	7 20 53 „	—	1 30	0.093	0.065	*Do.*
11*	„	9 47 01 „	—	(Observation wanting.)	—	—	[A strong explosion.]
12*	„	2 17 47 pm.	2.7	1 30	0.03	0.02	[Black smoke ejected.]
13	„	3 32 43 „	0.9	0 52	0.07	0.06	Sensible; quick in character.
14	„	10 02 48 „	—	—	—	—	[Sound like distant thunder.]
15*	21	0 16 37 „	—	1 20	0.08	0.047	[Smoke explosion.]
16	„	7 13 44 „	—	—	—	—	[Sound like distant thunder.]
17	„	7 17 19 „	—	—	—	—	*Do.*
18	„	7 21 29 „	—	—	—	—	*Do.*
19	22	6 57 54 „	—	—	—	—	*Do.*
20	„	11 15 35 „	1.4	1 00	0.015	0.015	Motion very slight.
21	23	0 02 32 „	—	—	—	—	[Detonation.]
22	„	7 20 27 „	0.0	0 40	0.014	0.010	Unfelt; quick in character.

(*)....Earthquake caused by an explosion of the Asama-yama.

No.	Date. (1911)	Time of Occurrence.	Duration of Preliminary Tremor.	Total Duration.	Maximum Motion.		Remarks.
					Longitudinal Component.	Transverse Component.	
	Jan.	h m s	s	m s	mm	mm	
23	23	9 27 16 pm.	(?)	1 30	0.002	—	Unfelt; very small.
24	24	0 22 26 am.	1.4	0 46	0.030	0.012	*Do.*
25*	26	11 21 03 „	1.4	1 00	0.045	0.025	Sensible, accompanied by ejection of black smoke.
26*	29	2 11 52 „	3.8	1 03	0.032	0.017	Unfelt.
27	30	9 38 19 „	—	—	—	—	[Detonation.]
	Feb.						
28	2	8 13 52 pm.	1.3	0 26	0.036	0.024	Sensible; quick in character.
28′	5	5 21 12 am.	2.4	0 49	0.004	0.005	The origin was in the vicinity of the town of Ueda.
28″	11	0 58 03 pm.	6.8	2 15	0.083	0.063	*Do.*
29	18	10 22 51 „	0.0	0 21	0.008	0.010	Unfelt; quick in character.
30	19	11 18 31 am.	1.2	0 13	0.050	0.025	*Do.*
31	„	11 18 56 „	1.0	0 8	0.005	0.005	*Do.*
32	„	11 28 41 „	1.6	0 13	0.030	0.050	*Do.*
33	„	11 33 58 „	0.8	0 28	0.005	0.020	*Do.*
34	„	11 41 42 „	1.4	0 33	0.060	0.120	Sensible; quick in character.
35	„	0 21 11 pm.	1.1	0 10	0.005	0.017	Unfelt; „ „ „
36	22	1 28 56 „	—	—	(Small)	0.002	[Sound like distant thunder.]
37	„	1 29 04 „	—	—	(Small)	0.003	*Do.*
38	„	11 47 04 „	0.9	0 46	0.074	0.060	Sensible; quick in character.
39	25	3 15 16 am.	0.0	0 23	0.007	0.008	Unfelt; „ „ „

(*)....Earthquake caused by an explosion of the Asama-yama.

58. *Character of earthquake motion.* All the 39 earthquakes tabulated above, of which only 6 were sensible, were small disturbances; their maximum longitudinal and transverse movements being under 0.18 and 0.12 mm respectively. These may,

according to the character of motion, be divided into the two following categories:—(I), the shocks consisting only of minute quick vibrations; and, (II) those which began with slow movements, mixed after a few seconds, with quick vibrations. From Table XXX it will be seen that the earthquakes of Group (I) were accompanied by no outburst of the Asama-yama, while those of Group (II) were invariably the results each of an explosion of the latter.

59. *Volcanic earthquakes not accompanied by explosion.* According to Table XXX, the Asama-yama earthquakes not accompanied by eruptions were nineteen in number, namely, Nos. 1, 2, 3, 5, 13, 20, 22, 23, 24, 28 to 35, 38, and 39. The total duration of motion varied from 8 sec. to 1 min. 30 sec., giving the average value of 32 sec. To illustrate the character of motion of this sort of volcanic disturbances, I reproduce in Fig. 49 (Pl. XXXII) the diagrams of the shock on Feb. 22nd, 1911, at 11.47.04 pm, enlarged 8.7 times photographically, thus bringing the resultant magnification ratio to 870. In the longitudinal motion, the preliminary tremor had a duration of about 0.7 sec., while in the transverse motion it was longer and lasted 1.4 sec.; the max. 2a's in these two components being respectively 0.071 and 0.057 mm, and each occurring at the commencement of the respective principal portion. It follows that the maximum longitudinal motion arrived at Ashino-taira 0.7 sec. earlier than the maximum transverse. Denoting, therefore, by V_1 and V_2 the transit velocities of these two particular movements, we have:—

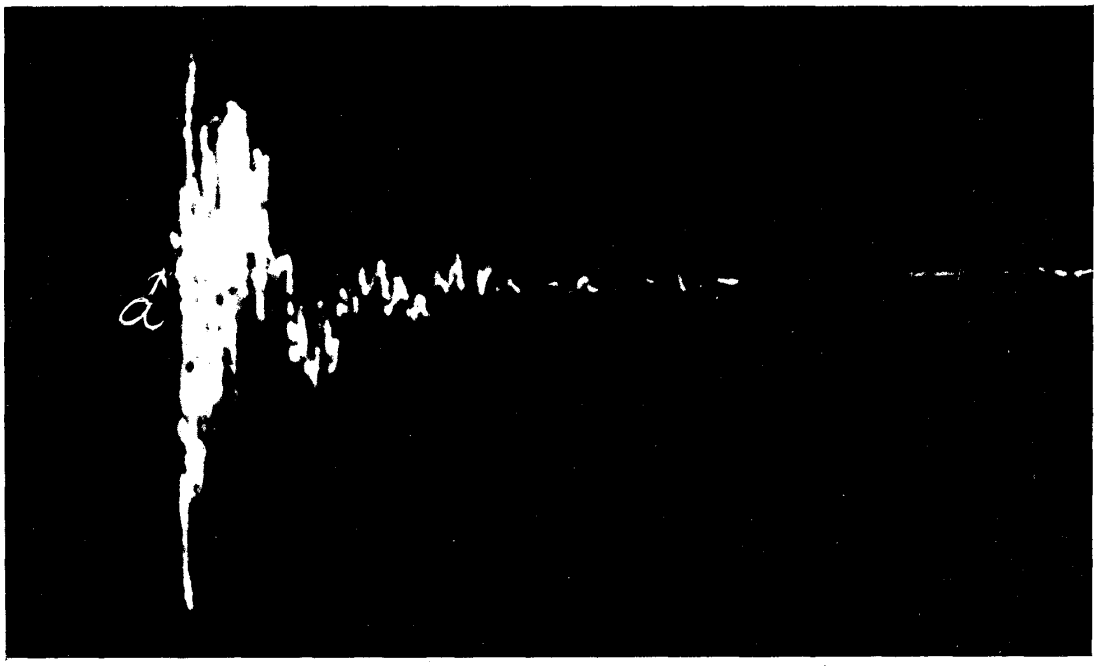
$$\frac{x}{V_2}=\frac{x}{V_1}+0.7 \text{ sec.},$$

in which x is the distance of Asino-taira from the earthquake origin. Supposing the latter to be situated right under the crater,

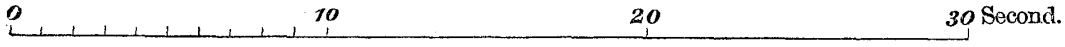
Fig. 49. Tromometer Observation at Ashino-taira, on the Asama-yama: Diagrams of a Volcanic Earthquake not accompanying an Eruption.

Asama-yama Earthquake of Feb. 22nd, 1911; 11.47.04 pm.

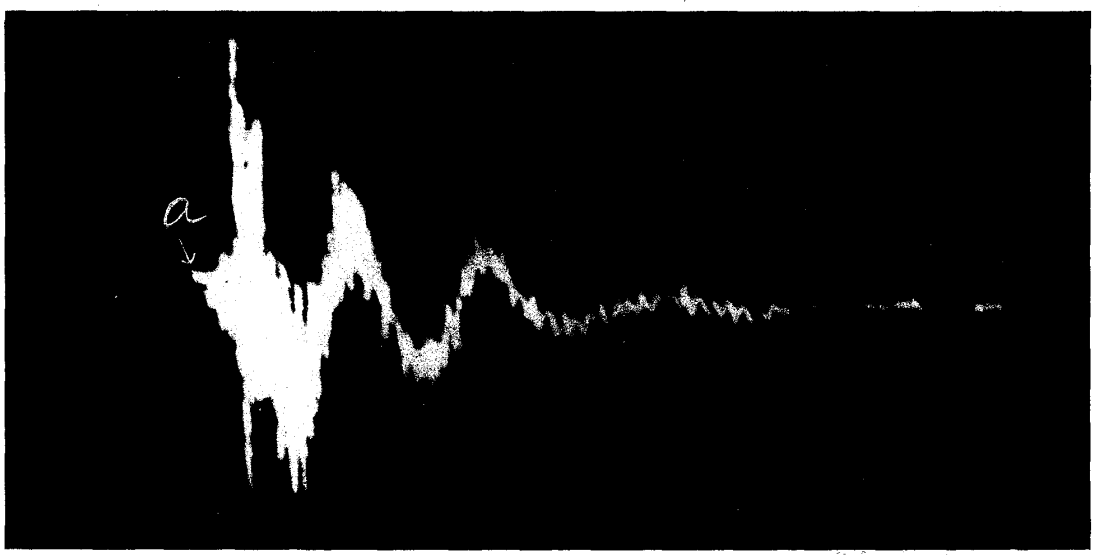
Longitudinal Vibration.



Time scale.



Transverse Vibration.

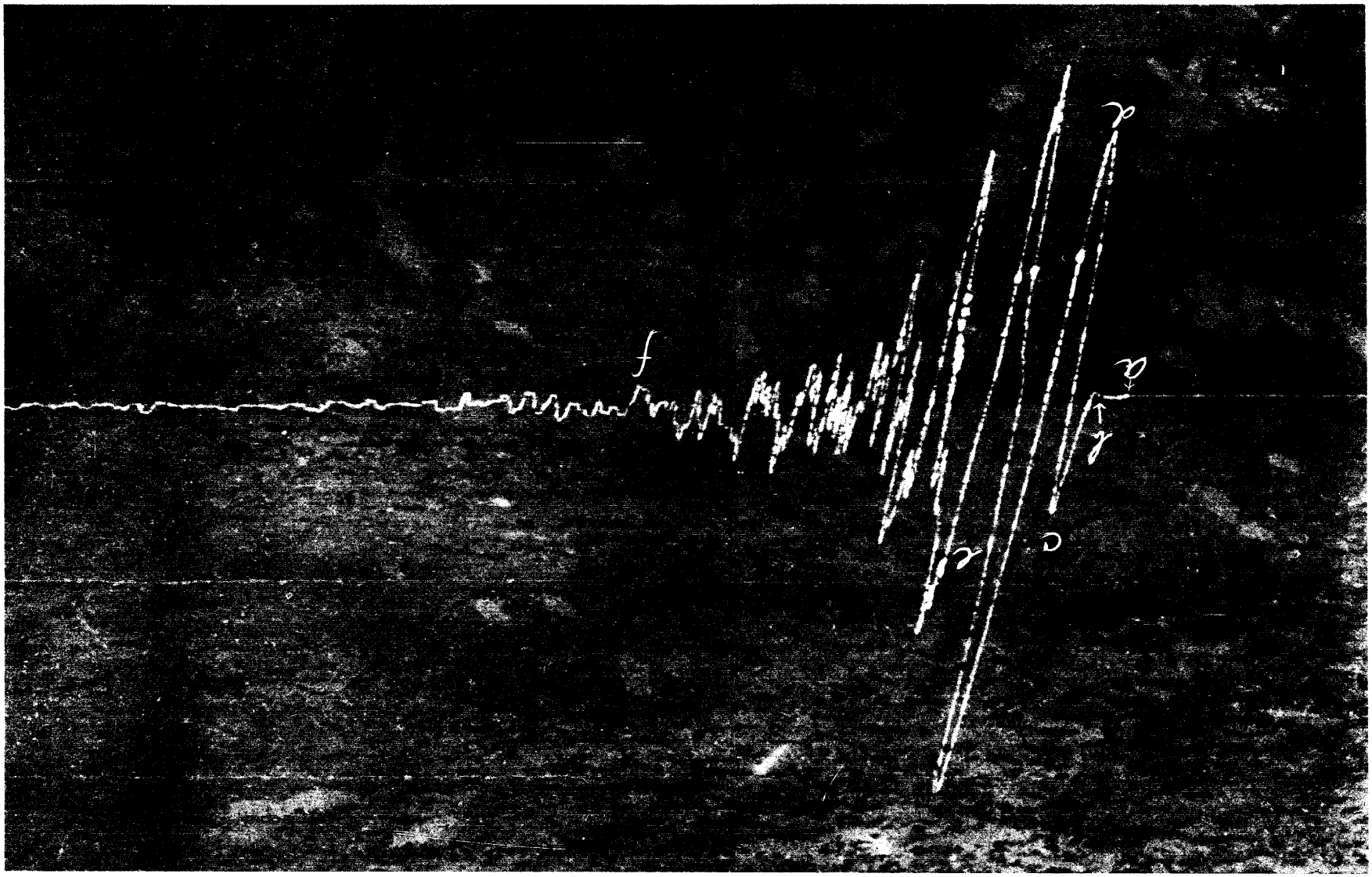


Magnification = 850.

Fig. 50. Tromometer Observation at Ashino-taira, on the Asama-yama:
Diagram of a Volcanic Earthquake accompanying an Eruption.

Asama-yama Earthquake of Jan. 17th, 1911; at 2.04.27 am.

Longitudinal Component. Magnification = 850.



0 10 20 30 40 50 60 Second.

Time Scale.

or putting $x=7.2$ km as deduced below, and also assuming $V_1 =$ 3.3 km per sec., the above equation gives

$$V_2=2.5 \text{ km/sec.};$$

in other words, the velocities of the maximum longitudinal and transverse vibrations are in the ratio of 1.3 : 1. Of course this result is to be regarded as only roughly approximate. Further, the diagrams of the different earthquakes were not necessarily alike with respect to the relative durations of the preliminary tremor in the two component movements, probably owing to the diversity in depth and in position of their origins.

The duration of the preliminary tremor ($=y$) in the longitudinal component of each of the different earthquakes was as follows :—

TABLE XXXI. DURATION OF THE PRELIMINARY TREMOR OF THE ASAMA-YAMA EARTHQUAKES NOT ACCOMPANIED BY EXPLOSIONS.

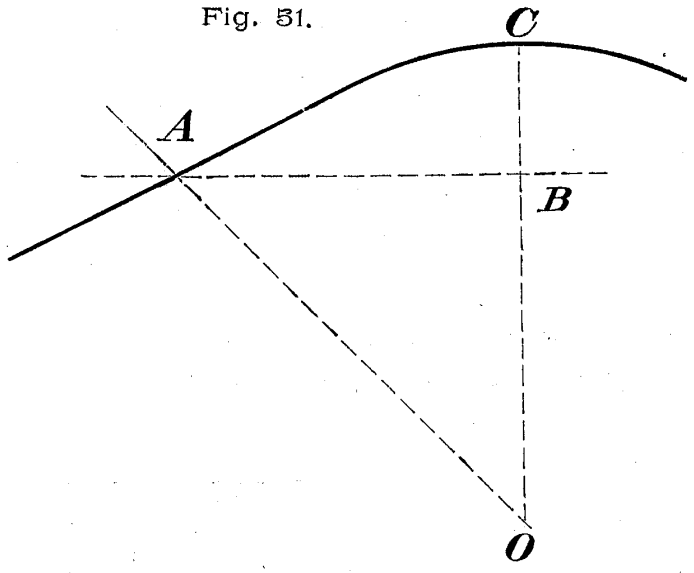
Eqke No.	y=Duration of Preliminary Tremor.	Eqke No.	y=Duration of Preliminary Tremor.
1	0.0 sec.	30	1.2 sec.
2	1.5	31	1.0
3	1.6	32	1.6
5	1.2	33	0.8
13	0.9	34	1.4
20	1.4	35	1.1
22	0.0	38	0.9
24	1.4	39	0.0
28	1.3		
29	0.0	*Mean*	**0.96**

Thus, y varied between 0.0 and 1.6 sec., giving the average of 0.96 sec. With this latter value of the preliminary tremor (y), the equation

$$x \text{ km} = 7.48\ y \text{ sec.}$$

gives $x = 7.2$ km for the distance between the place of observation and the mean origin of the earthquakes. Assuming the latter to be situated under the crater, which is about 5 km horizontally distant from Ashino-taira, it follows that the *mean* origin must be about 6 km below the mountain top, or about 4 km below the level of the mountain base (Komoro).

Fig. 51.



C.....Top (Crater) of the Asama-yama.
A .....Ashino-taira.
O .....Earthquake Centre.

The mean value of the maximum *apparent* longitudinal and transverse movements in the different earthquakes were nearly equal to each other, as follows:—

Longit. max. $2a$	0.030 mm.
Transv. max. $2a$	0.031 mm.

The relative insignificance of the apparent longitudinal component is probably on account of the *comparatively* great depth of the mean origin. Thus, according to what was said above (Fig. 51), the angle of emergence at Ashino-taira was 45°, the apparent or

horizontal longitudinal motion being only $1/\sqrt{2}$ of the real radial component. With regard to the transverse vibration, its direction may possibly be purely horizontal, that is to say, parallel to the contour line. If this be the case, the apparent or horizontal and the true transverse movements would be identical with each other, giving a value of $1 : \sqrt{2}$ for the ratio of the maximum transverse to the maximum longitudinal component of the earthquake motion, according to the numerical results above indicated. The apparent and true longitudinal movements will be mutually equal only when the origin of disturbance lies quite near to the surface or at the same level as the place of observation.

60. ***Earthquakes caused by explosions.*** To this category of volcanic disturbances belong the eleven earthquakes, namely, Nos. 4, 6, 7, 8, 9, 10, 11, 12, 15, 25, and 26. To illustrate the character of motion in the cases under consideration, I reproduce in Fig. 50 (Pl. XXXIII) the longitudinal (hor.) component diagram of the earthquake of Jan. 17th, 1911, at 2.04.27am, magnified photographically 8.5 times, which gives a resultant multiplication ratio of 850. The earthquake began with a preliminary tremor (*ab*) of 2.4 sec. duration, in which the motion was extremely small. The first and second displacements occurring at the commencement of the principal portion were as follows :—

1st displacement (*bc*).....0.028 mm, directed toward the crater;
2nd „ (*cd*) .....0.091 mm, „ from „ „ ;

these two making up a vibration of period of 2.6 sec. Then followed three large vibrations, whose $2a$'s were respectively 0.173 ; 0.134 ; and 0.092 mm, which having an average period of 4.2 sec., were probably the proper pendulum oscillations. The superposed quick vibrations began to distinctly appear (at *e*) from about 8,0 sec. after the commencement of the principal portion and

lasted about 25 sec., their elements of motion being as follows :—

Average $T=0.61$ sec., max. $2a=0.024$ mm.

Thereafter, the motion became gentle and the principal periods were 1.6 and 2.9 sec.; the total earthquake duration being about 1 min. 56 sec. The following remarks may be added :—

(i) The preliminary tremor (*ab*) is probably different in nature from that in ordinary non-volcanic earthquakes, and may be due to those disturbances occurring previous to the actual explosion, as for example, the extension or formation of an underground crack.

(ii) The slow vibration (*bcd*) at the beginning of the principal portion is probably of the nature of a bodily oscillation and due to the first bulging up and the consequent outward forcing of the mountain mass at the moment of the explosion, as explained in a preceding §.

The duration (y) of the preliminary tremor in the different earthquakes was as follows :—

Eqke No.	Duration (y) of the Preliminary Tremor.
4	2.4 sec.
6	1.3
12	2.7
25	1.4
26	3.8

The duration y, which thus varied between 1.3 and 3.8 sec., probably represents, as stated before, the time interval between the moment of the explosion and the occurrence of the precursory underground disturbance. The following table gives the duration

of, and the period in, the slow oscillation part at the commencement of the principal portion of the different earthquakes :—

TABLE XXXII. EARTHQUAKES OF THE ASAMA-YAMA CAUSED BY EXPLOSIONS.

Eqke No.	Slow Oscillation Part at the commencement of Principal Portion.	
	Duration.	Average Period.
4	9.0 sec.	2.6 sec.
6	8.0	2.5
7	6.5	2.6
8	5.6	2.0 ; 0.6 sec.
9	7.9	2.6
10	7.5	2.5 ; 0.6
11	—	—
12	7.0	2.1
15	9.0	3.0
25	7.0	2.7
26	8.7	2.0
Mean	7.6	2.6 ; 0.6

Thus the principal period in question was 2.6 sec., there being sometimes also a period of 0.6 sec.

The max. $2a$'s in the apparent longitudinal and transverse components were as follows :—

TABLE XXXIII. COMPARISON OF LONGITUDINAL AND TRANSVERSE MAX. 2A'S.

Eqke No.	Max. $2a$.		Ratio : $\frac{\text{Longit.}}{\text{Transv.}}$
	Longitudinal.	Transverse.	
4	0.175 mm.	0.045 mm.	3.89
6	0.060	0.045	1.33
7	0.026	0.020	1.30
8	0.070	0.050	1.40
9	0.123	0.075	1.64
10	0.093	0.065	1.43
11	—	—	—
12	0.030	0.020	1.50
15	0.080	0.047	1.70
25	0.045	0.025	1.80
26	0.032	0.017	1.88
Mean	—	—	1.79

Thus, on the average the apparent longitudinal motion was about 1.8 times larger than the apparent transverse one. The comparatively great value of this ratio probably indicates that the origins of the explosion-earthquakes are generally at a smaller depth than those of the shocks not accompanied by explosions, a supposition which looks perfectly natural.

61. *Causes of Asama-yama earthquakes.* According to what has been stated in the preceding § §, it seems that the volcanic earthquakes not accompanied by explosions are due to the underground expansive force, which produces cracks at depth of a few kilometres ; in other words, these shocks may be regarded

as ordinary local seismic disturbances, which consist of quick vibrations. On the other hand, the earthquakes directly due to volcanic explosions must be caused by the upward extension of the cracks, which were formed previously by the shocks of the other category, with a partial removal of the stress, and along which the outburst finally takes place. The motion produced, firstly, by the warping up of the superincumbent rock layer, and, secondly, by a forcible outward pushing of the mountain mass consequent to the explosion, will be propagated to the surrounding region as earthquake movements of slow character; the very first displacement being directed *toward*, and the second and much larger displacement *away from*, the origin of disturbance.

62. *Comparison with Nagano observations.* Of the 39 earthquakes observed at Ashino-taira, only eight, namely, Nos. 4, 6, 8, 9, 10,* 11, 12, and 15, were registered at the Nagano Meteorological Observatory. (See § 64.) The times of occurrence at these two places, although not accurate enough to enable us to make any suitable velocity calculation between them, are given in the following table.

TABLE XXXIV. COMPARISON OF ASHINO-TAIRA AND NAGANO EARTHQUAKE OBSERVATIONS.

Eqke No.	Date (1911).	Time of Occurrence	
		At Ashino-taira.	At Nagano.
4*	Jan. 17 am.	2h 04m 27s	2h 03m 30s
6*	18 pm.	1 08 19	1 08 30
8*	„ „	9 27 51	9 28 03
9*	19 am.	1 15 20	1 15 28

Eqke No.	Date (1911).	Time of Occurrence.	
		At Ashino-taira.	At Nagano.
10*	Jan. 19 am.	7h 20m 53s	7h 21m 02s
11*	,, ,,	9 47 01	9 46 58
12*	,, pm.	2 17 47	2 17 37
15*	21 ,,	0 16 37	0 17 05

* Earthquakes accompanied by explosions.

From the above list, it will be noted that all of the earthquakes which were registered at Nagano were accompanied by explosions; those not accompanied by explosions having altogether failed to make themselves sensible to a 30-times magnification horizontal pendulum at the above named place.

63. ***Tremors.*** The diagrams obtained at Ashino-taira indicated the existence of *micro-tremors*, or very minute non-seismic movements of short periods, only on Feb. 4th, between 1.41.06 and 5.23.34 pm. The tremors, which presented a character as if they were composed of a series of very small earthquakes, had two principal periods, whose average values were respectively 0.53 and 1.24 sec. The greatest movements, which occurred at 3.46.16 and 3.46.55 pm, were as follows:—

$$T=1.24 \text{ sec.} \begin{cases} \text{max. } 2a=0.007 \text{ mm (longit. component)} \\ \text{max. } 2a=0.007 \text{ ,, (transv. ,,)} \end{cases}$$

These micro-tremors are probably the result of the activity of the volcano, which made throughout the day under consideration explosions and detonations.

64. ***Note on earthquake observations at Nagano.*** A mechanical registration EW-component horizontal pendulum apparatus of 30 times magnification set up in the Meteorological Observa-

tory of Nagano, 40 km to the NW of the Asama-yama, recorded 23 earthquakes originating at that volcano, during the course of 3 months from Dec. 1910 to March 1911. The following table gives for each of them, the time of occurrence, the total duration, the duration of the preliminary tremor, and the max. $2a$.

TABLE XXXV. EW COMPONENT HORIZONTAL PENDULUM OBSERVATIONS OF THE ASAMA-YAMA EARTHQUAKES AT NAGANO.

Date.	Time of Occurrence.	Duration of Preliminary Tremor.	Total Earthquake Duration.	Max. $2a$.
	h m s		m s	mm
Dec. 2, 1910.	8 20 06 pm.	5.8 sec.	3 00	0.15
„ 16, „	8 05 20 am.	8.7	2 20	(Small)
Jan. 6, 1911.	2 07 41 am.	6.5	2 45	0.2
„ 17, „	2 01 30 am.	5.6	3 22	0.2
„ 18, „	1 08 30 pm.	4.5	3 17	0.1
„ „ „	9 27 03 pm.	4.2	2 51	0.1
„ 19, „	1 14 28 am.	5.0	3 49	0.15
„ „ „	3 25 10 am.	—	2 35	(Small)
„ „ „	7 21 02 am.	5.6	2 22	„
„ „ „	9 46 58 am.	—	1 52	„
„ „ „	2 17 37 pm.	—	3 01	„
„ 21, „	0 17 05 pm.	4.3	2 45	0.2
„ 24, „	10 30 29 am.	—	1 56	(Small)
Feb. 14, „	1 25 27 am.	—	4 09	„
„ 15, „	9 35 50 pm.	6.9	1 16	„
„ 19, „	6 28 52 am.	—	2 24	„
„ „ „	5 38 07 pm.	—	7 10	„
„ 20, „	10 42 58 am.	3.2	2 51	„
„ 21, „	5 08 52 am.	—	3 08	„
„ „ „	0 44 28 pm.	—	1 48	0.1
„ 26, „	3 52 38 pm.	4.3	2 06	(Small)
Mar. 21, „	2 46 10 am.	4.8	2 54	0.02 (period = 2.0^s)
„ „ „	9 10 40 am.	6.0	3 06	0.01 (period = 1.7^s)

The (EW component) max. $2a$'s at Nagano of the different earthquakes, which were all unfelt, were thus smaller than 0.2 mm, making the accurate determination of the duration (y) of the preliminary tremor often doubtful. The average value of y, however, comes out to be 5.4 sec., which according to the equation

$$x \text{ km} = 7.48\ y \text{ sec.}$$

gives $x = 40.3$ km for the distance between Nagano and the mean earthquake origin, perfectly identical with the actual value.

CHAPTER X. ELEVATION OF THE CRATER BOTTOM AND THE FUTURE ACTIVITY OF THE ASAMA-YAMA.

65. ***Signs of increasing activity.*** The subjects, whose investigations are of vital importance in connection with the volcanic activity of the Asama-yama, are two-fold, namely, (i), the elevation of the bottom of the crater, and, (ii), the seismic disturbances of the local origin. (i) may be regarded as indicating the rate of increase of the expansive force of the steam and gases accumulating under the volcano, and (ii) as the forerunners of the explosions.

66. ***Depth of crater in*** **1887.** In the years succeeding the great eruption of 1783, the Asama-yama crater was probably very deep, its diameter being appreciably smaller than at present. The first attempt to determine the depth of the crater was made, so far as I am aware, by Dr. John Milne and the former United States Minister, Mr. Edwin Dun, in 1887, or 104 years after the Temmei disaster. The following is an account of their experiment, in which the depth was found to be some 224 metres.

"The crater of this volcano, as it stands today, measures a mile and a quarter in circumference, and never ceases to belch