

CHAPTER XI. ORDINARY EARTHQUAKES OBSERVED AT YUNO-TAIRA, ASHINO-TAIRA, AND ASAMA PASTURE GROUND(THE ERUPTIONS AND EARTHQUAKES OF THE ASAMA-YAMA IV [Strong Asama-yama Outbursts, Dec. 1912 to May 1914])

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PASTURE GROUND.

107. In the next three §§ I give examples of the observations at the Asama-yama stations of ordinary earthquakes which originated in the vicinity of the volcano and those which originated at distances of over 100 km from it.

108. *Earthquakes of near origin observed at Yunotaira.*

Earthquake of Sept. 20th, 1912, at 11.40.04 p.m. The origin was in the neighbourhood of the town of Ueda.

Longitudinal Component: total duration= 2^m40^s . The preliminary tremor lasted 3.5 sec. and consisted of $1\frac{1}{2}$ vibrations of $T=2.4$ sec., $2a=0.0099$ mm, the 1st and outward displacement being 0.0034 mm. [Principal portion: duration= 47.8 sec.] During the 1st 5.2 sec., the motion was comparatively small and composed of two oscillations of $T=2.6$ sec., $2a=0.031$ mm, mixed with small vibrations of $T=0.38$ sec. For the next 11.3 sec., the motion was active, consisting of quick vibrations of $T=0.35$ sec., max. $2a=0.025$ mm, mixed with the slower ones of $T=0.87$ sec. During the remaining 31.5 sec., the motion consisted chiefly of the vibrations of $T=2.2$ sec., mixed with those of $T=0.91$ sec., the largest (absolute maximum) of which was $2a=0.065$ mm and occurred at the commencement of this phase. During the principal portion there were distinct traces of slow oscillations of $T=4.4$ sec. [End portion.] During the 1st 23.1 sec., the vibrations of $T=2.3$ sec. were mixed with the quicker ones of $T=0.93$ sec., $2a=0.011$ mm. Thereafter the motion became much smaller, being composed at first of the vibrations of $T=2.9$ sec., max. $2a=0.0054$ mm, mixed with quicker ones of $T=0.85$ sec. Toward the end, the period became about 1.5 sec.

Earthquake of Oct. 5th, 1911; at 11.51.22 p.m. The earthquake was felt *moderately* at the village of Omae (in Kozuke), and the towns of Ueda and Suzaka (in Shinano), respectively 12 km to the N, 24 km to the W, and 34 km to the N35°W, of the Asama-yama crater. It was sensible at Nagano, and recorded as an unfelt shaking by the ordinary seismographs at the meteorological observatories of Mito, Mount Tsukuba, and Matsumoto. According to the tremor-recorder diagram obtained at Yuno-taira, the first and the counter displacements were respectively 0.029 mm toward S87°E and 0.17 mm toward N75°W, giving the average direction of S81°E and N81°W. The earthquake origin was, judging from the area of disturbance, situated in the latter azimuth, near the town of Ueda.

In the tromometer record (ENE and WSW component), the motion, whose two introductory displacements were 0.028 and 0.150 mm toward ENE and WSW respectively, was most active for the first 13.4 sec., with the average T of 0.96 sec.; the absolute max. $2a$ of 0.18 mm occurring 3.6 sec. after the commencement. During the next 13.1 sec., the motion was smaller but still active: max. $2a=0.054$ mm, $T=0.93$ sec. During the next 19.2 sec., the vibrations of $T=1.9$ sec. ($2a=0.035$ mm) were mixed with those of $T=1.07$ sec. So far may be taken as the preliminary tremor and the principal portion. During the first 40.5 sec. of the end portion, the vibrations of $T=1.4$ sec. ($2a=0.013$ mm) were mixed with those of slower ones. In the subsequent portion the motion was very small: $2a=0.003$ mm, $T=2.9$ sec. As will be seen from the above account, the motion was large from the outset. The initial portion preceding the absolute maximum may, however, be taken as the preliminary

tremor, whose duration was then 3.6 sec., corresponding to the radial distance of about 27 km. The approximate position of the earthquake origin thus determined is about 4 km to the NW of Ueda, at $\varphi=36^{\circ}26'N$, $\lambda=138^{\circ}13'E$.

Observation in Tokyo. According to the 120-times EW-component tromometer diagram, the time of occurrence was 11.52.00 p.m., the duration of the preliminary tremor being 22.5 sec. During the 1st 17.9 sec. of the principal portion, the motion was comparatively small. During the next 50.4 sec., it was most active and consisted of $8\frac{1}{2}$ vibrations of $T=5.9$ sec., the 3rd displacement being the maximum, $2a=0.11$ mm. Total duration=6 min.

Observation at Nagano. Time of occurrence=11.51.55 p.m.: duration of preliminary tremor=3.3 sec.; max. $2a=0.47$ mm; total duration=4^m.

Earthquake of Oct. 6th, 1911; at 8.50.35 a.m. This earthquake, which was a little larger than the preceding, was felt *moderately* at Omae, Ueda, and Shiozaki (Sarashina county, Shinano), which last is 41 km to the N $68^{\circ}W$ from the Asama-yama crater. It was sensible at Nagano, and recorded as an unfelt shock by ordinary seismographs at the meteorological observatories of Tokyo, Kumagai, Matsumoto, Kofu, Nagoya, and Osaka. According to the tremor-recorder diagram obtained at the Yuno-taira observatory, the earthquake began quite sharply with a displacement of 0.04 mm directed toward N $89^{\circ}E$, the counter motion being 0.24 mm directed toward N $67^{\circ}W$. These give the average direction of S $78^{\circ}E$ and N $78^{\circ}W$, the earthquake origin being probably situated in the latter azimuth, and quite near to that of the shock on the 5th.

In the tromometer diagram (ENE-WSW component), the motion, whose two introductory displacements were 0.044 and 0.21 mm toward ENE and WSW respectively, was most active for the

first 14.5 sec., with the average T of 1.1 sec.; the absolutely max. $2a$ of 0.32 mm occurring 5.4 sec. after the commencement. There were also vibrations of $T=2.7$ sec. During the next 13.9 sec., the motion consisted of well defined quick vibrations of $T=1.0$ sec. ($2a=0.10$ mm). During the next 19.7 sec., the motion was smaller and consisted of the vibrations of $T=1.0$ sec. ($2a=0.061$ mm), mixed with those of $T=2.5$ sec. Thereafter the motion rapidly decreased.

Observation in Tokyo. According to the 120-times EW-component tromometer record, the time of commencement was 8.50.46 a.m., the duration of the preliminary tremor being about 21.1 sec. During the 1st 20.0 sec. of the principal portion, the motion was comparatively small. For the next 54.0 sec., it was most active, and consisted of $8\frac{1}{2}$ vibrations of $T=6.4$ sec., the 3rd displacement being the maximum, $2a=0.2$ mm. Total duration=6 min.

Observation at Nagano. Time of occurrence=8.50.24 a.m.; duration of preliminary tremor=4.6 sec.; max. $2a=0.72$ mm; total duration= 5^m12^s .

Earthquake of Aug. 13th, 1913, at 4. 27. 20 a.m. The earthquake originated from the vicinity of the city of Matsumoto. Longit. Compt.: total duration= $2^m 16^s$. The preliminary tremor, which was clearly indicated, lasted 6.5 sec., and consisted of small vibrations of $T=0.27$ sec., mixed with those of $T=0.55$ sec., $2a=0.0019$ mm. [Principal portion: duration=10.4 sec.] During the 1st 0.6 sec., the motion was small: max. $2a=0.0046$ mm. For the next 2.5 sec., the vibrations were quick and most active: max. $2a=0.028$ mm. During the remaining 7.3 sec., the vibrations gradually decreased to $2a=0.0073$ mm. [End portion.] The motion was composed of vibrations of $T=0.84$ sec., max. $2a=0.0033$ mm, mixed with the quicker ones of $T=0.33$ sec.

109. Examples of distant eqkes observed at Yuno-taira.

Earthquake of July 9th, 1912, at 5.31 p.m. The earthquake originated off the coast of Kii. Longitudinal Compt.; total duration= $8^m 8^s$. The preliminary tremor lasted 46.3 sec. and consisted of vibrations of $T=1.5$ sec., max. $2a=0.013$ mm, mixed with others of longer and shorter periods. [Principal portion: duration= $3^m 7^s$.] During the 1st 59.4 sec., the vibrations of $T=5.5$ sec., max. $2a=0.036$ mm, were mixed with those of $T=2$ sec. and others, the period of the slow superposed oscillations being about 26.4 sec. During the remaining $2^m 08^s$, the motion was composed of vibrations of $T=8.3$ sec., max. $2a=0.051$ mm mixed with smaller ones. [End portion.] The vibrations of $T=6.8$ sec., max. $2a=0.013$ mm, were mixed with the small ones of $T=2.1$ sec.

Earthquake of Sept. 30th, 1912, at 9.34 p.m. The earthquake originated off the E. coast of Kazusa. Longit. Compt.; total duration= 15^m . During the 1st 13.1 sec., the motion was very small. During the next 13.5 sec., the vibrations were larger: $T=1.04$ sec., max. $2a=0.012$ mm. [Principal portion: duration= $1^m 41^s$.] During the 1st 30.8 sec., the slow vibrations of $T=3.4$ sec., max. $2a=0.029$ mm, were mixed with some smaller ones. During the next 32.0 sec., the motion was largest and composed chiefly of the vibrations of $T=1.8$ sec., of which the max. $2a$ of 0.043 mm occurred at the commencement and at the end. During the remaining 38.0 sec., the vibrations of $T=2.0$ sec., max. $2a=0.016$ mm, with mixture of quicker ones, were grouped into slow oscillations of $T=6.6$ sec. [End portion.] Vibrations of $T=2.2$ sec. were grouped into those of $T=4.4$ sec., max. $2a=0.014$ mm.

110. Distant eqkes observed at Asama Pasture Ground.

Earthquake of Oct. 16th, 1913. This earthquake, which was slightly felt in Tokyo at $9^h 17^m 29^s$ a.m., originated near the

south-eastern coast of the province of Kazusa, at a radial distance of about 210 km to the S50°E of the Asama-yama, so that the two horizontal components at the Asama Pasture Ground, oriented respectively in the directions at right angles and parallel to the line pointing to the crater, were approximately the longitudinal and transverse components with respect to the origin of the earthquake in question. Total earthquake duration=2^m 40^s. [Longitudinal or SSE-NNW Component.] During the 1st 6.9 sec., the motion was composed principally of quick vibrations of T=0.29 sec., max. 2a=0.0175 mm. For the next 4.5 sec., the movements were slower. For the next 5.6 sec., the motion was most active, consisting of well defined quick vibrations of T=0.24 sec., max. 2a=0.0302 mm, mixed more or less distinctly with those of T=0.63 sec. For the next 11.1 sec., the motion was composed principally of vibrations of T=0.69 sec., max. 2a=0.029 mm, at first mixed with quick ones of T=0.27 sec., max. 2a=0.0207 mm. For the next 13.2 sec., the movements were much smaller: T=0.68 sec., max. 2a=0.0156 mm. The subsequent motion was very slight. [Transverse or ENE-WSW Component.] During the 1st 6.8 sec., the vibrations were, as in the other component, nearly uniform: T=0.29 sec., max. 2a=0.0136 mm. For the next 8.0 sec., the motion was gentle and composed of slower movements of max. 2a=0.0086 mm. The next 10.3 sec. forms the most active portion of the earthquake and consisted of the quick vibrations of T=0.24 sec., max. 2a=0.038 mm, mixed with those of T=0.64 sec. During the next 20.4 sec., the motion was composed principally of the slow vibrations; the large ones (max. 2a=0.030 mm), which occurred at the commencement having the period of 0.72 sec. The subsequent motion was smaller.

Earthquake of Nov. 14th, 1913, at 11^h 4^m a.m. This earth-

quake was felt slightly at Kofu, and registered as an unfelt shaking at the meteorological observatories of Fukushima, Utsunomiya, Mito, Kumagai, Yokohama, Numazu, Matsumoto, and Tokyo; the time of occurrence at the Seismological Institute, where the preliminary tremor lasted about 13 sec., being 11^h 4^m 19^s a.m. The origin of disturbance was in the north-western part of the province of Musashi, i.e. at a distance of about 50 km to the SE of the Asama-yama. The two horizontal pendulums of the tremor-recorder at the Asama Pasture Ground oriented for the longitudinal and the transverse directions with respect to the movements emanating from the volcanic centre, registered in the present case respectively the approximate transverse and the longitudinal components of the earthquake motion. The earthquake had been preceded by a small fore-shock 1^m 37^s before. Total duration=127 sec. [Longitudinal or SSE-NNW Component.] The vibrations were small for the 1st 4.0 sec.: $T=1.0$ sec., $2a=0.0037$ mm. For the next 31.2 sec., the motion was composed of the vibrations of $T=0.73$ sec., max. $2a=0.026$ mm, mixed with some quick movements of $T=0.26$ sec., and grouped more or less definitely into slow oscillations of about 5.3 sec. period. During the remaining 25.2 sec. of the principal portion, the vibrations were free from the superposition of the quick movements and a little smaller than before: $T=0.83$ sec., max. $2a=0.026$ mm. The subsequent motion was much smaller. [Transverse or ENE-WSW Component.] The motion, which was distinctly indicated first from 5.4 sec. after the commencement of the earthquake, consisted, for the next 30.8 sec., of the vibrations principally of $T=0.71$ sec., max. $2a=0.031$ mm, with the mixture of some quick movements. During the remaining 28.9 sec. of the principal portion, the vibrations, which became a little smaller, were free from the superposition of the latter,

being, as before, grouped into slow oscillations of $T=6.3$ sec. [Comparison of Longitudinal and Transverse Components.] The first distinct movement was indicated 5.4 sec. earlier in the longitudinal than in the transverse component. There was, however, no special difference between the two with respect to the individual vibrations composing the earthquake motion.

III. Remarks on ordinary earthquakes and non-eruptive volcanic earthquakes observed at Yuno-taira and Asama Pasture Ground. The mean values of the different group periods (Tables XXVI and XXVII) found in the different ordinary earthquakes observed at Yuno-taira and at the Asama Pasture Ground (§§ 108 to 110) are as follows:—

	Yuno-taira.	Asama Pasture Ground
(i).....	26.4 sec.....	— sec.
(ii)	6.0	5.4
(iii)	2.2	—
(iv)	0.95	0.76
(v)	0.38	0.28

The periods of the most frequently occurring vibrations are (iii) and (iv), namely, 2.2 sec. and 0.95 sec. at Yuno-taira, and (iv) and (v), namely, 0.76 sec. and 0.28 sec. at the Asama Pasture Ground. The period (ii), namely, 6.0 or 5.4 sec., is probably of the nature of the pulsatory oscillations. Had the earthquakes been sufficiently large, there would have been also periods much longer than (i), or 26.4 sec.

As referred to in § 99, the periods of vibration, (ii) to (v), in the ordinary earthquakes are also found in the shakings caused by the Asama-yama eruptions.

From the analysis of a few seismograms given in Chapter X, it seems likely that the motion of the non-eruptive volcanic earth-

quakes also contains a number of periods similar to those found in the ordinary shocks. The duration of the earthquake motion due to the individual eruptions, whether strong or weak, was always short, being at the different Asama-yama stations less than 260 sec. In the case of the non-eruptive volcanic shocks of sharp character, as described in § 103, the total duration was much shorter; the duration of the principal portion being, in particular, momentary, so to speak, and varying from 2.0 to 6.5 sec. The disturbances of this nature, whose record on a small time-scale smoked-paper consists apparently of a single jerk or dot, are each made up of course of a number of very quickly decreasing vibrations.

TABLE XXVI. PERIODS* OF VIBRATION IN ORDINARY EARTHQUAKES OBSERVED AT THE ASAMA PASTURE GROUND.

(Mean values are printed in thick figures.)

sec.	sec.	mm.	sec.	mm.
6.3	1.00	(0.0037)	0.32	(0.048)
5.4	0.92	(0.016)	0.30	(0.044)
5.3	0.85	(0.025)	0.29	(0.018)
<u>4.6</u>	0.83	(0.026)	0.29	(0.014)
5.4	0.79	(0.003)	0.27	(0.021)
	0.78		0.26	
	0.73	(0.026)	0.24	(0.030)
	0.72	(0.030)	<u>0.24</u>	<u>(0.038)</u>
	0.71	(0.031)	0.28	
	0.71			
	0.69	(0.029)		
	0.68	(0.016)		
	0.64			
	<u>0.63</u>			
	0.76			

* Collected from the two components.

TABLE XXVII. PERIODS* OF VIBRATION IN ORDINARY EARTHQUAKES OBSERVED AT YUNO-TAIRA.

(Mean values are printed in thick figures.)

Preliminary Tremor.	Principal Portion.		End Portion.
sec. mm. 2.4 (0.01)	sec.	mm. sec.	sec. mm. 6.8 (0.013)
1.5 (0.013)		1.10 (0.32)	4.4
1.04 (0.012)	8.3 (0.051)	1.07	<u>5.6</u>
0.55 (0.002)	6.6	1.00 (0.10)	2.9 (0.003)
0.27	5.5 (0.036)	1.00 (0.061)	2.9 (0.0054)
	4.4	0.96 (0.18)	2.3
	<u>6.2</u>	0.93 (0.054)	2.2
		0.91 (0.065)	2.1
		<u>0.87</u>	1.5
	3.4 (0.029)	0.98	<u>1.4 (0.013)</u>
	2.7		2.2
	2.6 (0.031)	0.38	0.93 (0.011)
	2.5	<u>0.35 (0.025)</u>	0.85
	2.2	0.37	<u>0.84 (0.0033)</u>
	2.0 (0.016)		0.87
	2.0		0.33
	1.9		
	<u>1.8 (0.043)</u>		
	2.3		

* Relating to the ENE-WSW component.