

Observation of Local Earthquakes on Mount Tsukuba, in 1905.

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With Pls. I—VI.

Place of observation. The present paper is a preliminary report on the seismometrical measurements made in 1905 at H.I.H. Prince Yamashina's meteorological station at Tsukuba, a small town at mid-height of the southern slope of the Tsukubasan. The latter is a mountain of granite and diorite formations, which is situated in the south-western part of the province of Hitachi, and which rises, almost as a solitary mass, to an elevation of 870 metres, directly out from the low plain bordering the lower course of the river Tone and the Kasumiga-ura. The geographical position of the meteorological station in question, which is 240 metres above the sea level, is $\varphi=36^{\circ} 12' 22''$ N., $\lambda=140^{\circ} 5' 56''$ E. A full account of these earthquake observations as well as those made at His Highness' Meteorological Observatory, established in 1901, at the top of one of the double peaks of the Tsukubasan, will be given as an appendix to the "Ergebnisse der meteorologischen Beobachtungen auf dem Tsukubasan."

Instrument. The observations, whose object was the study of the near earthquakes, were made with an EW component

horizontal tremor-recorder*, (shown in the accompanying figure), whose instrumental constants were as follows :

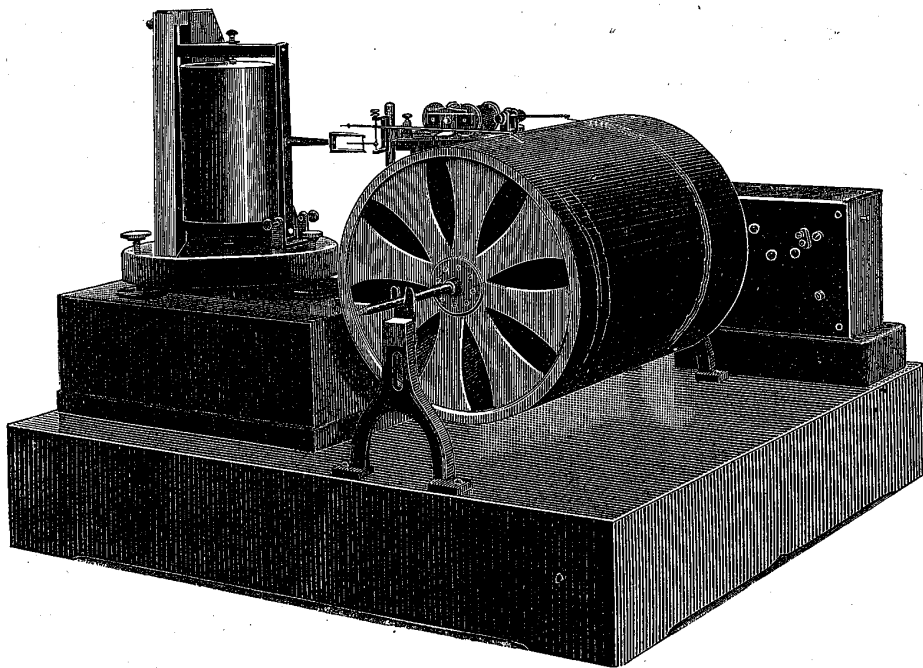
Weight of the heavy bob=about 15 kg.

Multiplication ratio of the pointer=90.

Natural period of the horizontal pendulum=about 4 sec.

Rate of motion of the smoked paper wrapped round the revolving drum=about 8-16 mm per minute.

As the town of Tsukuba is very quiet and free from the effect of traffic and similar artificial disturbances, the site of the meteorological station is particularly well adapted to the observation of the small local shocks ; there being no great amount of the pulsatory oscillations, due to the rocky nature of the mountain. On account of the same latter circumstance, the majority of the sensible earthquakes were preceded or accompanied by sounds.



* This instrument is similar to those described in the "Publications," No. 18, and the "Bulletin," Vol. I, No. 4.

The observations have been carried on by Mr. J. Sato, chief observer of the Tsukuba observatories, Mr. H. Tsutsui, assistant observer, and others.

List of the earthquakes observed in 1905. The tremor-recorder is sensible only to the quicker component of the seismic motion, and recorded, in 1905, four hundred and eighty-seven earthquakes, whose epicentral distances were each less than 1,000 km, which is nearly equal to the distance of the Tsukuba-san from either the north-eastern end of Hokkaido on the north, or the northern part of Kyushu on the south-west. The accompanying list gives for the EW component of each of these shocks, the following particulars:—

- (1) Date.
- (2) Time of earthquake occurrence, given in the 1st Normal Japan Time, or that of longitude 135° E. of Greenwich.
- (3) Intensity of motion, distinguished as *slight*, or *moderate*. None of the earthquakes was *strong* or *destructive*.*
- (4) Total duration.
- (5) Duration of the preliminary tremor.
- (6) Maximum range of motion in the preliminary tremor.
- (7) „ „ „ „ principal portion.
- (8) Remarks.

The preliminary tremor was in most cases quite sharply defined.

* The intensity of the non-destructive earthquake motion is indicated as slight, moderate, or strong. A slight shock is one which is very feeble and just enough to be felt; a moderate shock is one whose motion is well-pronounced but not so severe as to cause general alarm; and a strong shock is one which is sufficiently intense to cause people to run out of doors, to overturn furnitures, etc.

List of 487 Earthquakes observed on Mount Tsukuba
in 1905.

(* denotes an *insensible* shock.)

Date.	Time of Occurrence.	Intensity.	Total Duration.	Duration of Prel. Tremor.	Max. Motion in		Remarks.
					Prel. Tremor.	Principal Portion.	
	January.						
1	^{h m s} 4 30 30 a.m.	Slight.	^{sec.} 106	^{sec.} 16.4	^{mm.} 0.010	^{mm.} 0.082	
"	8 53 10 p.m.	Do.	26	14.2	—	0.013	
2	2 27 25 a.m.	*	37	11.3	—	0.006	
"	4 25 30 a.m.	*	31	8.2	0.007	0.014	
5	0 25 06 a.m.	Slight.	30	5.6	0.004	0.028	Accompanied by loud sound.
7	10 57 00 a.m.	Moderate.	64	9.9	0.013	0.033	
9	4 00 50 p.m.	*	29	9.4	—	0.009	Sound only perceived.
11	1 23 10 a.m.	*	23	8.7	—	0.011	Do.
13	11 25 30 a.m.	Slight.	23	6.0	0.006	0.044	Accompanied by sound.
14	1 09 00 p.m.	*	40	41.0	—	0.002	
"	5 38 30 p.m.	Moderate.	65	5.9	0.004	0.058	Accompanied by sound.
17	4 19 00 a.m.	Slight.	22	6.7	0.015	0.080	
"	10 59 20 a.m.	Do.	36	10.4	—	0.008	Accompanied by sound.
21	7 44 27 a.m.	Do.	35	5.9	—	0.011	Accompanied by loud sound.
"	5 29 00 p.m.	*	70	6.0	—	0.004	Sound only perceived.
22	2 53 00 a.m.	Slight.	78	13.1	0.008	0.026	
"	0 58 40 p.m.	*	16	8.1	—	0.039	
25	8 30 37 p.m.	Slight.	31	8.4	0.011	0.060	
26	1 55 15 p.m.	*	—	10.3	—	—	
"	4 02 30 p.m.	Moderate.	106	11.0	0.028	0.220	
"	5 19 28 p.m.	*	120	46.0	—	0.003	
"	7 14 10 p.m.	*	90	(?)	—	0.004	Origin distant.
27	9 23 10 p.m.	*	60	(?)	—	0.002	Do.

Date.	Time of Occurrence.	Intensity.	Total Duration.	Duration of Prel. Tremor.	Max. Motion in		Remarks.
					Prel. Tremor.	Principal Portion.	
	January.						
28	^{h m s} 1 48 30 a.m.	*	sec. 30	sec. 6.6	mm. —	mm. —	
	February.						
2	8 17 00 a.m.	*	133	63.0	—	0.010	
„	9 08 25 a.m.	Slight.	98	24.0	—	0.022	
4	0 54 30 a.m.	Do.	30	9.5	0.020	0.037	
5	3 58 00 p.m.	*	35	11.6	—	0.022	
6	5 21 00 a.m.	*	40	16.8	—	0.017	
7	11 33 00 a.m.	*	85	22.5	—	0.011	
„	2 46 45 p.m.	Moderate.	100	17.0	0.036	0.120	
„	8 49 05 p.m.	Slight.	20	0.0	—	0.072	Accompanied by loud sound.
11	7 05 30 a.m.	Moderate.	70	25.0	0.022	0.073	Accompanied by sound.
13	1 55 10 p.m.	Slight.	32	8.0	—	0.010	Do.
14	10 55 45 p.m.	Moderate.	140	18.5	0.001	0.047	Do.
15	10 13 00 a.m.	*	65	16.4	—	0.022	
„	5 29 30 p.m.	Slight.	66	7.1	0.011	0.038	Accompanied by sound.
„	9 12 00 p.m.	*	20	0.0	—	0.022	
17	2 06 40 a.m.	Slight.	21	0.0	—	—	Accompanied by sound.
„	3 27 25 a.m.	Do.	87	19.5	0.009	0.054	Do.
„	10 56 30 a.m.	*	14	8.0	—	0.016	Do.
„	5 14 25 p.m.	Slight.	72	5.7	0.013	0.076	Do.
„	6 44 30 p.m.	Moderate.	144	14.1	0.027	0.180	Do.
18	6 56 05 p.m.	Slight.	100	10.1	—	0.024	Do.
„	7 08 10 p.m.	*	36	13.2	—	—	Sound only perceived.
20	1 47 33 p.m.	Slight.	24	8.5	0.012	0.064	Accompanied by sound.
21	2 26 30 p.m.	*	44	0.0	—	—	Sound only perceived.
23	9 03 20 a.m.	*	46	6.0	—	—	Do.

Date.	Time of Occurrence.	Intensity.	Total Duration.	Duration of Prel. Tremor	Max. Motion in		Remarks.
					Prel. Tremor.	Principal Portion.	
	February.						
23	h m s 11 35 00 p.m.	*	sec. 24	sec. 9.2	mm. 0.004	mm. 0.010	
24	4 18 50 a.m.	Slight.	40	14.1	0.004	0.038	
25	2 45 00 a.m.	*	34	7.7	—	0.010	
„	3 13 00 a.m.	*	—	—	—	—	Only loud sound perceived.
„	6 44 15 a.m.	Moderate.	47	14.3	0.017	0.098	Accompanied by sound.
„	0 54 00 p.m.	*	22	7.0	0.003	0.008	
27	1 19 45 a.m.	Slight.	59	12.1	0.009	0.036	Accompanied by sound.
	March.						
3	4 12 05 p.m.	*	53	6.0	0.004	0.012	
„	5 17 40 p.m.	*	20	7.1	—	0.014	
4	3 39 45 a.m.	Slight.	43	8.9	—	0.024	Accompanied by sound.
„	9 18 30 p.m.	Moderate.	76	9.0	0.022	0.170	Do.
6	6 04 25 a.m.	Slight.	40	8.2	0.004	0.047	Accompanied by sound.
„	6 08 15 a.m.	Do.	65	8.8	0.004	0.060	Do.
8	7 04 00 a.m.	*	47	15.3	—	0.012	
9	3 33 00 a.m.	Slight.	183	14.6	0.024	0.057	Accompanied by sound.
12	8 19 30 a.m.	Do.	34	11.3	0.002	0.014	Do.
„	8 12 30 p.m.	Do.	21	6.2	0.020	0.043	Do.
14	4 10 45 p.m.	*	49	8.4	0.004	0.028	
„	7 16 40 p.m.	*	33	11.0	—	0.006	
16	1 06 11 p.m.	Slight.	41	9.4	0.024	0.044	Accompanied by sound.
18	1 09 35 p.m.	Do.	33	11.8	0.006	0.060	Do.
„	10 30 00 p.m.	Do.	27	7.0	—	0.039	Do.
19	11 11 30 p.m.	*	64	35.0	—	0.009	
21	2 58 20 a.m.	Slight.	63	7.8	—	0.021	Accompanied by sound.
„	10 57 25 a.m.	Do.	106	36.0	0.002	0.020	Do.

Date.	Time of Occurrence.	Intensity.	Total Duration.	Duration of Prel. Tremor.	Max. Motion in		Remarks.
					Prel. Tremor.	Principal Portion.	
	March.						
23	h m s 7 02 25 a.m.	*	sec. 67	sec. 15.0	mm. —	mm. 0.013	
„	5 59 00 p.m.	Slight.	40	13.1	0.007	0.038	Accompanied by sound.
24	11 16 00 a.m.	*	31	14.2	—	0.009	
25	2 00 00 a.m.	*	52	19.6	—	0.006	
26	8 04 00 a.m.	Slight.	30	3.5	—	0.028	Accompanied by sound.
„	9 33 30 p.m.	*	18	5.2	0.002	0.039	
	April.						
3	7 50 00 p.m.	*	94	18.6	—	—	
6	9 29 10 p.m.	Moderate.	68	6.7	0.093	0.490	{ Loud sound heard toward S., 5 or 6 sec. before the shock. Houses were much shaken, and liquids thrown out. The rain gauge was displaced slightly toward SW.
„	11 33 40 p.m.	*	39	6.3	0.008	0.029	
10	0 25 30 a.m.	*	34	9.6	0.004	0.021	
11	3 44 40 a.m.	*	21	0.0	—	0.036	
12	7 23 10 a.m.		19	6.0	0.003	0.042	Sound only perceived.
13	0 37 25 p.m.	*	51	17.2	—	0.016	
„	6 02 40 p.m.	Slight.	70	9.0	0.018	0.064	{ Loud sound heard toward S. before the shock.
14	1 00 00 a.m.	*	21	7.3	—	0.011	
„	7 37 00 a.m.	Slight.	48	25.2	—	0.044	
17	3 11 05 a.m.	*	31	7.8	—	0.028	
„	7 13 00 p.m.	*	123	65.0	—	0.006	
9	1 02 00 a.m.	*	10	5.6	—	0.006	
„	5 29 00 a.m.	*	35	10.3	—	0.004	
20	8 45 30 a.m.	*	45	17.4	—	0.016	
21	1 28 00 a.m.	*	24	7.4	—	0.011	
„	11 07 30 p.m.	*	42	7.7	—	0.006	

Date.	Time of Occurrence.	Intensity.	Total Duration.	Duration of Prel. Tremor	Max. Motion in		Remarks.
					Prel. Tremor.	Principal Portion.	
April.							
	h m s		sec.	sec.	mm.	mm.	
22	3 34 00 a.m.	*	84	17.3	—	0.008	
24	1 04 00 a.m.	*	85	22.2	—	0.016	
„	5 15 02 a.m.	Moderate.	65	15.7	0.017	0.153	Accompanied by sound.
„	6 31 00 a.m.	Do.	60	11.6	0.024	0.094	Do.
25	3 42 00 a.m.	*	45	8.5	—	0.016	
27	0 31 00 p.m.	Slight.	18	5.4	0.004	0.021	{ Loud sound heard toward SW.
29	7 17 30 a.m.	*	Very Short.	0.0	—	—	{ The diagram consisted only of a single stroke.
30	9 34 10 a.m.	*	50	12.2	0.013	0.024	
„	7 37 30 p.m.	Slight.	25	4.9	—	0.036	{ Preceded by loud sound, which was heard toward S. The principal portion of the diagram lasted only 3.5 sec.
May.							
2	3 00 45 p.m.	*	58	9.8	—	0.016	
4	5 51 50 p.m.	*	11	0.0	—	0.014	
5	4 04 05 a.m.	*	28	8.7	—	Small.	
„	8 13 20 a.m.	*	30	9.0	—	0.010	
7	6 27 00 p.m.	*	40	10.6	—	0.004	
„	10 20 10 p.m.	*	39	6.1	—	0.016	
„	10 24 20 p.m.	*	100	35.0	—	Small.	
8	8 12 55 p.m.	Moderate.	80	19.0	—	0.051	Accompanied by sound.
9	2 54 10 a.m.	Do.	149	11.0	0.051	0.204	Loud sound heard toward S.
13	7 32 00 p.m.	*	31	7.9	—	0.004	
15	8 07 25 a.m.	Slight.	68	9.2	0.017	0.061	Accompanied by sound.
16	2 51 00 a.m.	*	52	8.3	—	0.029	
7	2 06 30 a.m.	*	130	62.0	—	0.013	
„	8 32 10 a.m.	*	30	6.2	—	0.011	
„	10 03 00 a.m.	Slight.	43	5.3	0.006	0.044	

Date.	Time of Occurrence.	Intensity.	Total Duration.	Duration of Prel. Tremor.	Max. Motion in		Remarks.
					Prel. Tremor.	Principal Portion.	
May.							
	h m s.		sec.	sec.	mm.	mm.	
20	4 53 30 p.m.	*	95	49.3	—	0.016	
22	6 23 30 p.m.	*	30	8.9	0.008	0.024	
23	5 18 15 a.m.	*	23	6.1	0.006	0.028	
„	1 33 25 p.m.	*	20	7.4	—	0.028	
„	7 45 00 p.m.	*	70	12.3	—	0.014	
24	8 32 30 p.m.	Slight.	109	41.0	—	0.024	
25	1 29 30 a.m.	Do.	41	5.2	0.009	0.077	
26	2 00 25 a.m.	Do.	60	10.1	0.010	0.058	Accompanied by sound.
„	3 46 50 p.m.	Moderate.	107	19.4	0.043	0.160	{ Loud sound heard toward S., 3 sec. before the shock.
28	0 50 00 a.m.	*	17	—	—	Small.	
„	1 49 00 a.m.	*	18	—	—	„	
31	8 56 00 p.m.	*	65	12.0	0.002	0.011	
June.							
2	1 17 50 p.m.	*	27	8.3	—	0.017	
3	0 44 30 a.m.	*	53	15.0	—	0.006	
„	11 21 30 a.m.	Slight.	53	8.8	0.004	0.016	Accompanied by sound.
4	8 45 30 a.m.	*	70	6.4	—	0.003	
5	8 43 30 a.m.	*	35	(P)	—	0.008	
„	10 01 30 a.m.	*	25	8.9	—	0.008	
6	0 40 00 a.m.	*	28	(P)	—	Small.	
„	0 43 00 a.m.	*	31	19.6	—	0.007	
„	1 13 00 a.m.	*	55	19.1	—	0.009	
„	1 18 00 a.m.	*	40	(P)	—	0.004	
6	1 49 00 a.m.	*	57	18.0	—	0.013	
„	2 04 00 a.m.	*	62	21.2	—	0.019	
„	2 25 00 a.m.	*	60	17.8	—	0.008	

Date.	Time of Occurrence.	Intensity.	Total Duration.	Duration of Prel. Tremor.	Max. Motion in		Remarks.
					Prel. Tremor.	Principal Portion.	
	June.						
6	h m s 2 27 00 a.m.	*	sec. 60	sec. ?	mm. —	mm. Small.	
„	5 17 00 a.m.	*	58	20.3	—	0.009	
„	5 57 30 a.m.	Moderate.	54	7.0	0.013	0.106	{ Loud sound heard toward SW.
„	9 19 00 a.m.	*	8	?	—	Small.	
„	9 23 00 a.m.	*	27	?	—	0.009	
„	11 45 30 a.m.	*	10	?	—	Small.	
7	6 12 30 a.m.	Moderate.	74	6.1	0.032	0.190	{ Loud sound heard toward SW.
„	2 39 50 p.m.	Do.	75	17.7	0.027	0.093	{ Loud sound heard toward SE.
„	2 41 05 p.m.	Slight.	91	17.2	0.027	0.083	
„	3 28 50 p.m.	*	10	?	—	Small.	
„	3 41 50 p.m.	*	7	?	—	„	
„	3 42 30 p.m.	*	—	18.3	—	0.008	
„	10 05 30 p.m.	*	40	16.7	—	0.031	
10	3 09 50 p.m.	Slight.	106	36.4	0.017	0.042	Accompanied by sound.
11	11 50 10 p.m.	Moderate.	49	5.6	0.066	0.220	{ Loud sound heard toward SW., 3 sec. before the shock.
12	5 17 30 p.m.	Do.	154	18.4	0.054	0.190	{ Sound heard toward S., 5 sec. before the shock, and ceased during the motion.
13	2 48 30 p.m.	*	95	29.0	—	Small.	
14	8 44 30 a.m.	*	28	11.1	—	0.012	
16	7 08 20 p.m.	*	20	?	—	Small.	Origin distant.
17	2 12 00 a.m.	*	20	7.7	—	0.007	
„	5 33 00 a.m.	*	30	?	—	Small.	Origin distant.
18	1 16 24 a.m.	Moderate.	100	13.2	0.023	0.190	Accompanied by sound.
„	2 15 30 a.m.	*	15	?	—	Small.	Origin distant.
„	3 33 15 a.m.	*	25	?	—	0.013	Do.
„	9 50 00 a.m.	*	10?	?	—	0.016	Do.
„	11 02 00 a.m.	*	5	?	—	0.021	{ The diagram consisted of a single stroke.

Date.	Time of Occurrence.	Intensity.	Total Duration.	Duration of Prel. Tremor.	Max. Motion in		Remarks.
					Prel. Tremor.	Principal Portion.	
	June.						
19	h m s 6 38 30 a.m.	Slight.	sec. 18	sec. 6.6	mm. —	mm. 0.027	Accompanied by sound.
20	5 31 00 a.m.	Do.	75	18.3	0.007	0.050	Do.
„	0 34 10 p.m.	*	15	6.1	—	0.010	
„	0 37 40 p.m.	*	145	114.0	—	0.009	
26	1 23 00 a.m.	Slight.	55	16.0	0.012	0.056	Accompanied by sound.
„	1 38 20 p.m.	Do.	50	13.3	0.008	0.039	{ Loud sound heard toward S.
27	1 09 30 a.m.	*	160	54.0	0.007	0.039	
„	3 17 10 a.m.	Slight.	50	12.1	0.028	0.183	Accompanied by sound.
„	3 46 30 p.m.	*	35	9.9	—	0.006	
29	10 29 00 a.m.	Slight.	30	8.1	0.002	0.008	Accompanied by sound.
„	4 59 00 p.m.	*	20	7.1	0.002	0.007	
	July.						
2	10 58 00 p.m.	*	10	?	—	0.002	
3	4 43 00 p.m.	*	30	17.8	—	0.008	
„	11 14 20 p.m.	*	40	10.3	—	0.002	
4	6 58 20 p.m.	*	?	13.1	—	0.013	
5	2 08 30 a.m.	*	30	13.2	0.003	0.007	
„	9 00 30 a.m.	*	60	?	0.006	0.011	Origin distant.
„	2 37 10 p.m.	Slight.	40	10.1	0.003	0.010	Sound heard toward S.
7	1 21 25 a.m.	Moderate.	275	?	0.032	0.690	Origin distant. No sound.
„	1 26 00 a.m.	Slight.	95	32.0	0.012	0.071	
„	4 51 40 a.m.	*	35	?	—	0.010	Origin distant.
„	7 17 25 a.m.	Moderate.	225	62.0	0.077	0.170	Accompanied by sound.
„	9 06 30 a.m.	*	25	?	—	Small.	Origin distant.
„	10 19 00 a.m.	*	30	?	—	0.006	Do.
„	10 38 00 a.m.	*	100	60.0	0.006	0.011	

Date.	Time of Occurrence.	Intensity.	Total Duration.	Duration of Prel. Tremor.	Max. Motion in		Remarks.
					Prel. Tremor.	Principal Portion.	
	July.						
7	^{h m s} 9 27 45 p.m.	*	sec. 50	sec. 9.9	mm. —	mm. 0.016	
„	10 38 35 p.m.	*	70	?	—	0.013	Origin distant.
8	3 13 00 a.m.	*	70	37.5	—	0.014	
„	7 20 30 a.m.	*	20	?	—	Small.	Origin distant.
„	11 08 00 a.m.	*	50	23.0	—	0.018	
9	7 11 55 a.m.	Moderate.	160	29.3	0.050	0.150	Accompanied by weak sound.
„	7 21 30 a.m.	*	15	?	—	0.004	Origin distant.
„	11 23 00 a.m.	Slight.	45	9.1	—	0.049	Accompanied by loud sound.
10	2 49 20 a.m.	*	60	?	—	0.003	Origin distant.
„	7 55 00 a.m.	*	—	28.0	—	0.010	
11	4 55 00 a.m.	*	30	10.1	—	0.028	
„	6 18 25 a.m.	Slight.	105	22.5	0.012	0.048	Accompanied by sound.
12	0 38 25 a.m.	*	75	?	—	0.024	Origin distant.
„	0 41 00 a.m.	*	90	?	—	0.087	Do.
„	11 56 10 a.m.	*	21	4.7	0.002	0.004	Loud sound heard toward S.
13	5 05 15 a.m.	*	50	?	—	Small.	Origin distant.
„	1 53 00 p.m.	*	50	?	—	Do.	Do.
„	9 27 25 p.m.	*	40	?	—	0.004	Do.
14	6 02 30 a.m.	*	40	?	—	Small.	Do.
„	3 56 45 p.m.	*	75	18.2	—	0.011	
„	11 17 20 p.m.	*	—	9.5	—	0.003	
15	3 09 10 a.m.	Slight.	20	5.3	0.003	0.027	Accompanied by sound.
„	8 01 55 a.m.	Do.	60	11.5	0.004	0.033	Do.
„	7 07 30 p.m.	*	50	9.7	—	0.036	
16	3 38 25 p.m.	*	20	9.7	—	0.007	
„	4 08 30 p.m.	*	45	7.0	—	0.014	
19	3 27 30 a.m.	*	35	?	—	0.006	Origin distant.

Date.	Time of Occurrence.	Intensity.	Total Duration.	Duration of Prel. Tremor	Max. Motion in		Remarks.
					Prel. Tremor	Principal Portion	
	July.						
19	^{h m s} 5 03 12 p.m.	Moderate.	sec. 70	sec. 9.3	mm. 0.022	mm. 0.120	
„	6 39 00 p.m.	*	40	?	—	Small.	Origin distant.
20	4 33 15 a.m.	Slight.	25	5.7	—	0.022	Accompanied by sound.
„	5 35 20 a.m.	Do.	15	8.0	0.002	0.061	Do.
„	11 54 00 a.m.	Do.	30	4.4	0.027	0.082	{ Sound heard toward SW. before the shock.
„	5 49 10 p.m.	Slight.	55	?	—	0.028	
21	6 03 00 a.m.	*	75	10.9	—	0.039	
22	6 15 10 p.m.	*	70	28.0	—	0.007	
„	11 56 30 p.m.	*	26	?	—	Small.	Origin distant.
23	5 25 30 p.m.	Slight.	85	25.0	—	0.056	Accompanied by sound.
„	6 27 00 p.m.	Do.	40	19.7	—	0.051	Do.
„	7 00 20 p.m.	Moderate.	105	19.0	0.031	0.107	Sound heard toward S.
24	6 11 05 a.m.	*	60	?	—	Small.	Origin distant.
25	3 09 30 a.m.	*	45	?	—	0.017	Do.
26	0 49 20 a.m.	*	60	20.0	—	0.008	
„	1 04 30 a.m.	*	60	11.4	—	0.007	
„	4 30 07 a.m.	Slight.	55	6.2	0.016	0.073	{ Loud sound heard toward SW.
„	2 40 35 p.m.	Do.	65	16.0	—	0.022	
„	4 16 30 p.m.	*	60	20.5	—	0.028	
27	1 38 15 a.m.	Moderate.	100	7.9	0.039	0.340	Accompanied by loud sound.
„	2 09 30 p.m.	*	35	?	—	0.006	Origin distant.
29	4 57 30 a.m.	*	60	?	—	0.016	Do.
„	6 05 45 a.m.	Slight.	30	6.9	—	0.060	{ Loud sound heard toward SW., before the shock.
30	3 36 00 a.m.	*	90	53.0	—	0.007	
„	1 27 15 p.m.	*	?	32.5	—	Small.	
„	10 46 00 p.m.	*	30	?	—	Do.	Origin distant.

Date.	Time of Occurrence.	Intensity.	Total Duration.	Duration of Prel. Tremor.	Max. Motion in		Remarks.
					Prel. Tremor.	Principal Portion.	
	August.						
	h m s		sec.	sec.	mm.	mm.	
1	8 08 30 a.m.	*	20	8.3	—	0.006	
2	4 24 30 a.m.	*	40	?	—	Small.	Origin distant.
„	2 17 50 p.m.	*	40	?	—	Do.	Do.
4	3 40 00 a.m.	*	95	30.0	0.008	0.018	
„	8 51 30 a.m.	*	85	30.0	0.003	0.024	
„	9 02 00 a.m.	*	60	30.0	—	Small.	
5	2 29 30 p.m.	*	45	—	—	Do.	Origin distant.
6	9 19 00 a.m.	*	40	?	—	0.006	
„	6 28 40 p.m.	*	50	12.2	—	0.006	
9	5 17 20 a.m.	Slight.	45	16.2	0.003	0.076	Accompanied by sound.
10	6 26 10 p.m.	*	55	15.7	—	0.012	
„	9 00 45 p.m.	*	50	?	—	Small.	Origin distant.
11	0 19 25 a.m.	*	110	23.6	0.011	0.028	
12	9 27 30 p.m.	Slight.	40	8.3	—	0.039	Accompanied by sound.
15	9 23 30 a.m.	*	60	?	—	Small.	Origin distant.
„	10 40 30 a.m.	*	140	69.0	—	0.011	
„	5 12 50 p.m.	*	100	?	—	0.009	Origin distant.
„	5 37 10 p.m.	*	100	?	—	Small.	Do.
16	7 47 21 a.m.	*	50	19.4	—	0.003	
„	9 02 51 a.m.	*	80	27.0	—	0.011	
17	9 37 10 p.m.	*	80	30.0	—	0.030	
18	1 08 43 a.m.	Slight.	90	9.0	0.008	0.053	Accompanied by sound.
„	10 51 38 a.m.	*	60	19.0	—	0.006	
20	0 47 40 a.m.	Slight.	10	2.5	—	0.022	{ Accompanied by loud sound. The diagram consisted almost only of a single stroke.
21	2 28 37 a.m.	*	40	?	—	0.002	
22	11 32 07 p.m.	*	90	35.0	—	0.006	Origin distant.

Date.	Time of Occurrence.	Intensity.	Total Duration.	Duration of Prel. Tremor.	Max. Motion in		Remarks.
					Prel. Tremor.	Principal Portion.	
	August.						
23	^{h m s} 2 03 42 p.m.	*	sec. 35	sec. ?	mm. —	mm. Small.	Origin distant.
„	11 45 57 p.m.	*	30	6.7	0.002	0.004	
24	1 33 55 a.m.	Slight.	55	13.3	0.003	0.031	
„	3 01 17 a.m.	*	40	?	—	0.003	Origin distant.
„	0 05 38 p.m.	Moderate.	75	6.3	0.044	0.780	Loud sound heard toward S.
25	6 49 10 p.m.	Slight.	235	99.0	0.061	0.097	Accompanied by sound.
26	3 52 10 p.m.	Do.	26	6.7	0.002	0.009	Do.
„	4 18 00 p.m.	*	30	?	—	Small.	Origin distant.
„	5 33 10 p.m.	*	30	?	—	Do.	Do.
27	3 40 56 p.m.	*	70	?	—	0.020	Origin distant.
28	4 10 00 a.m.	*	80	?	—	0.014	Do.
„	8 56 00 a.m.	*	40	?	—	0.002	Do.
29	1 27 30 a.m.	Slight.	60	8.4	—	0.028	Accompanied by sound.
„	3 04 23 a.m.	*	30	14.5	—	0.004	
„	1 23 57 p.m.	*	30	?	—	Small.	Origin distant.
„	7 51 54 p.m.	*	55	25.0	—	0.007	
„	7 55 35 p.m.	Slight.	40	9.6	—	0.018	
30	1 15 42 a.m.	*	30	7.9	—	0.009	
„	9 27 02 a.m.	*	40	23.0	—	Small.	
31	7 40 15 a.m.	*	40	9.7	—	0.006	
„	1 17 46 p.m.	Slight.	55	8.8	—	0.030	Accompanied by sound.
„	1 35 45 p.m.	*	50	12.5	—	0.017	
	September.						
1	9 39 44 a.m.	Slight.	95	40.0	—	0.022	Accompanied by sound.
„	11 43 30 a.m.	Moderate.	220	79.0	0.032	0.150	Sound heard toward S.
2	0 53 23 a.m.	*	120	36.0	—	0.013	

Date.	Time of Occurrence.	Intensity.	Total Duration.	Duration of Prel. Tremor	Max. Motion in		Remarks.
					Prel. Tremor	Principal Portion.	
	September.						
2	h m s 3 35 12 p.m.	*	sec. 20	sec. ?	mm. —	mm. Small.	Origin distant.
„	3 43 25 p.m.	*	110	34.3	0.002	0.017	
„	4 26 30 p.m.	Moderate.	90	13.1	0.006	0.094	Loud sound heard toward S.
„	7 05 10 p.m.	*	70	12.3	—	0.016	
3	2 03 20 a.m.	Moderate.	140	10.6	0.012	0.150	Sound heard toward S.
4	7 32 30 a.m.	Slight.	30	6.9	—	0.006	Accompanied by sound.
„	8 49 35 a.m.	Do.	70	9.2	0.003	0.044	Do.
6	1 02 00 a.m.	*	60	?	—	0.007	Origin distant.
8	0 01 12 a.m.	*	60	?	—	0.002	Do.
9	11 35 17 p.m.	*	40	?	—	0.010	Do.
10	4 54 21 a.m.	*	40	?	—	0.004	Do.
11	4 38 38 p.m.	*	90	30.0	—	0.010	
„	7 52 10 p.m.	*	30	?	—	Small.	Origin distant.
„	10 16 20 p.m.	*	20	?	—	Do.	Do.
12	10 03 45 a.m.	*	20	?	—	Do.	Do.
„	11 36 25 a.m.	*	—	8.3	—	0.002	
13	5 36 15 p.m.	Slight.	70	7.4	0.003	0.017	Accompanied by loud sound.
14	2 44 05 a.m.	Do.	25	6.8	0.003	0.022	Accompanied by sound.
„	8 36 50 p.m.	*	50	8.4	—	0.003	
15	1 21 25 a.m.	*	40	?	—	0.002	Origin distant.
„	2 13 35 p.m.	Slight.	50	12.0	0.002	0.022	Accompanied by sound.
16	6 35 30 a.m.	*	40	14.6	—	0.002	
17	3 54 01 a.m.	*	60	?	—	0.004	Origin distant.
„	4 34 43 a.m.	*	30	?	—	0.003	Do.
„	4 58 54 p.m.	*	40	17.6	—	0.004	
„	9 03 00 p.m.	*	80	32.8	—	0.003	
„	9 46 30 p.m.	*	30	9.3	—	Small.	

Date.	Time of Occurrence.	Intensity.	Total Duration.	Duration of Prel. Tremor.	Max. Motion in		Remarks.
					Prel. Tremor.	Principal Portion.	
	September.						
18	^{h m s} 10 17 20 a.m.	*	sec 80	sec. 21.0	mm. —	mm. 0.018	
„	9 01 45 p.m.	*	120	39.0	—	0.006	
19	10 48 00 a.m.	*	60	?	—	0.007	Origin distant.
„	10 38 30 p.m.	*	30	7.8	—	0.010	
20	4 22 10 p.m.	Slight.	65	8.4	0.002	0.038	{ Loud sound of some duration heard toward S.
21	9 58 40 p.m.	*	40	?	—	0.002	Origin distant.
„	10 00 55 p.m.	Moderate.	120	9.7	0.250	0.860	No sound.
22	11 45 30 a.m.	*	70	?	—	0.011	Origin distant.
„	6 07 25 p.m.	*	120	40.2	0.006	0.024	
23	3 34 10 a.m.	*	25	10.0	—	0.002	
„	3 42 25 a.m.	*	25	?	—	0.004	Origin distant.
„	11 21 30 a.m.	*	30	?	—	0.007	Do.
„	4 42 30 p.m.	*	25	?	—	0.002	Do.
24	2 08 40 a.m.	Moderate.	85	7.8	0.031	0.210	Sound heard toward SW.
25	9 16 28 p.m.	Slight.	Short.	0.0	—	0.022	Accompanied by sound.
26	3 25 36 p.m.	Do.	70	9.0	0.017	0.050	{ Loud sound heard toward SW.
27	9 47 28 p.m.	*	120	24.0	0.006	0.025	
29	7 22 00 p.m.	Slight.	25	5.8	0.002	0.007	Accompanied by sound.
30	8 44 55 p.m.	*	70	?	—	0.014	Origin distant.
	October.						
1	6 18 00 a.m.	Slight.	25	7.6	—	0.013	
2	7 47 10 a.m.	*	40	6.6	—	0.006	
„	10 56 20 a.m.	Moderate.	160	10.0	0.097	0.580	
3	2 53 45 a.m.	Slight.	35	10.6	—	0.002	
„	4 12 25 p.m.	Do.	35	3.6	—	0.036	Accompanied by loud sound.
„	7 50 46 p.m.	Do.	60	9.1	0.014	0.026	Do.

Date.	Time of Occurrence.	Intensity.	Total Duration.	Duration of Prel. Tremor.	Max. Motion in.		Remarks.
					Prel. Tremor.	Principal Portion.	
	October.						
4	^{h m s} 8 15 55 a.m.	*	sec. Long.	sec —	mm. —	mm. —	Origin distant.
..	2 40 55 p.m.	Slight.	Short.	Short.	—	—	Accompanied by loud sound.
5	1 53 44 a.m.	*	60	14.7	—	0.017	
6	8 51 40 p.m.	Slight.	25	5.9	—	0.007	Accompanied by loud sound.
8	6 11 10 a.m.	*	50	18.0	—	0.002	
10	5 10 55 a.m.	*	180	88.0	0.007	0.017	
..	10 54 10 a.m.	Moderate.	145	9.2	0.061	0.430	Loud sound heard toward S.
..	11 10 55 a.m.	Slight.	30	?	—	0.020	
..	1 49 20 p.m.	Do.	60	?	—	0.039	Origin distant.
..	2 08 00 p.m.	Dp.	240	95.0	0.011	0.076	
..	2 28 20 p.m.	Do.	90	?	—	0.056	Origin distant.
..	2 36 10 p.m.	*	90	?	—	0.017	Do.
..	2 58 50 p.m.	*	120	?	—	0.020	Do.
..	3 22 10 p.m.	*	60	?	—	0.038	Do.
..	4 52 30 p.m.	*	40	?	—	Small.	Do.
..	8 51 15 p.m.	Slight.	90	39.0	—	0.038	Loud sound heard toward S.
..	9 34 35 p.m.	*	70	1.14	—	0.011	
..	9 46 40 p.m.	*	60	23.4	—	Small.	
11	9 13 05 a.m.	*	70	?	—	Do.	Origin distant.
..	3 43 18 p.m.	*	60	16.0	—	0.011	
12	8 06 00 a.m.	*	40	10.0	—	0.004	
13	9 27 15 p.m.	*	40	?	—	Small.	Origin distant.
14	11 54 20 a.m.	Moderate.	80	5.7	0.044	0.249	Accompanied by sound.
..	4 33 05 p.m.	Slight.	Short.	10.0	—	0.018	
15	6 46 35 a.m.	Do.	60	12.0	—	0.030	Accompanied by sound.
16	0 34 27 p.m.	*	60	15.1	—	0.011	
..	4 20 55 p.m.	*	60	?	—	Small.	Origin distant.

Date.	Time of Occurrence.	Intensity.	Total Duration.	Duration of Prel. Tremor.	Max. Motion in		Remarks.
					Prel. Tremor.	Principal Portion.	
	October.						
17	^{h m s} 1 21 00 p.m.	*	sec. 40	sec. ?	mm. —	mm. 0.006	Origin distant.
„	4 52 10 p.m.	*	30	?	—	0.033	Do.
18	4 59 45 a.m.	*	40	?	—	0.003	Do.
„	5 00 50 a.m.	*	50	10.0	—	0.006	
„	5 04 55 a.m.	*	50	9.3	—	0.002	
„	9 54 05 p.m.	*	70	10.2	—	0.013	
19	9 10 20 a.m.	Moderate.	85	9.8	0.060	0.120	Accompanied by sound.
„	9 04 20 p.m.	*	50	?	—	0.004	Origin distant.
20	2 43 30 a.m.	*	60	?	—	0.017	Do.
„	1 42 10 p.m.	*	40	?	—	0.004	Do.
„	2 16 00 p.m.	*	90	43.0	—	0.011	
22	9 38 10 a.m.	*	75	?	—	0.018	Origin distant.
„	9 39 55 a.m.	*	60	?	—	0.018	Do.
„	11 42 30 a.m.	*	85	?	—	0.028	Do.
„	11 43 35 p.m.	*	60	14.4	—	0.031	
23	6 00 00 p.m.	*	40	8.9	—	0.012	
24	0 43 10 p.m.	Moderate.	180	50.0	0.008	0.058	
25	11 12 40 p.m.	*	100	?	—	0.004	Origin distant.
26	6 01 50 a.m.	*	90	?	—	0.003	Do.
27	1 29 25 a.m.	*	60	?	—	0.003	Origin distant.
28	6 47 15 p.m.	*	60	?	—	0.013	Do.
30	7 36 00 a.m.	*	60	8.3	0.006	0.013	
„	11 32 30 p.m.	*	60	?	—	0.003	Origin distant.
31	1 02 40 p.m.	*	35	10.4	—	0.003	
	November.						
1	2 01 50 p.m.	Moderate.	180	?	—	0.140	No sound. Origin distant.

Date.	Time of Occurrence.	Intensity.	Total Duration.	Duration of Prel. Tremor	Max. Motion in		Remarks.
					Prel. Tremor.	Principal Portion.	
	November.						
1	h m s 2 11 15 p.m.	Slight.	sec. 60	sec. ?	mm. —	mm. 0.007	Accompanied by sound.
„	3 35 10 p.m.	*	70	?	—	0.007	Origin distant.
„	7 46 45 p.m.	Slight.	50	10.9	—	0.012	Accompanied by sound.
2	11 22 48 a.m.	Moderate.	110	12.9	0.073	0.190	No sound.
4	8 36 10 a.m.	Do.	80	11.4	0.019	0.120	Accompanied by sound.
5	2 12 40 a.m.	*	40	13.0	—	0.011	
„	3 32 50 p.m.	*	40	8.4	—	0.010	
8	11 11 20 p.m.	*	60	8.6	0.011	0.030	
9	5 56 00 a.m.	*	70	?	—	0.011	Origin distant.
„	7 19 50 p.m.	*	70	?	—	0.011	Do.
10	7 34 00 p.m.	Slight.	15	6.6	0.002	0.019	Accompanied by sound.
11	3 41 25 a.m.	*	60	19.7	—	0.018	
„	7 25 35 p.m.	Slight.	60	19.5	—	0.027	Accompanied by sound.
12	1 52 00 a.m.	Do.	80	10.6	0.007	0.071	Do.
„	8 53 10 a.m.	Do.	60	18.9	—	0.039	
16	10 28 30 p.m.	*	60	?	—	0.006	Origin distant.
19	0 49 50 a.m.	*	85	37.5	—	0.007	
„	2 51 24 a.m.	Slight.	50	4.5	0.003	0.044	Accompanied by loud sound.
„	6 08 05 p.m.	Do.	30	2.2	—	0.007	„ „ sound.
20	8 19 55 a.m.	*	45	16.0	—	0.007	
22	1 02 00 a.m.	*	25	—	—	—	
„	4 27 50 a.m.	*	60	—	—	—	
23	0 04 00 a.m.	*	30	—	—	—	
„	0 11 00 a.m.	*	120	50.0	—	—	
„	7 30 10 a.m.	*	85	—	—	—	
„	3 34 20 p.m.	*	80	—	—	—	
24	6 31 20 a.m.	Slight.	50	15.9	—	0.050	Accompanied by sound.

Date.	Time of Occurrence.	Intensity.	Total Duration.	Duration of Prel. Tremor	Max. Motion in		Remarks.
					Prel. Tremor.	Principal Portion.	
	November.						
24	^{h m s} 8 29 00 p.m.	Slight.	^{sec.} 35	^{sec.} 12.8	^{mm.} —	^{mm.} 0.041	Accompanied by loud sound.
26	6 16 20 p.m.	Do.	70	11.1	0.006	0.044	„ „ sound.
27	0 34 10 p.m.	Do.	150	31.3	0.007	0.037	Do.
28	6 02 10 p.m.	Do.	40	8.3	—	0.018	Do.
29	8 05 10 a.m.	*	50	11.4	—	0.014	
„	11 45 55 p.m.	*	30	?	—	Small.	Origin distant.
30	10 31 00 p.m.	*	50	13.7	—	0.003	
	December.						
2	2 15 45 p.m.	Slight.	85	24.0	—	0.028	Accompanied by sound.
„	11 27 10 p.m.	*	55	9.9	—	0.016	
3	1 40 45 a.m.	*	60	9.8	—	0.020	
„	0 40 55 p.m.	Slight.	80	17.2	—	0.022	Accompanied by sound.
„	1 46 40 p.m.	Do.	140	29.0	0.014	0.061	
„	9 02 20 p.m.	Do.	30	6.2	—	0.003	Accompanied by sound.
5	1 07 10 a.m.	*	35	9.5	—	0.002	
„	1 20 40 a.m.	*	100	23.0	0.007	0.032	
„	4 38 45 a.m.	*	120	52.0	—	0.010	
6	10 20 10 p.m.	*	70	23.2	—	0.006	
„	11 09 40 p.m.	*	35	11.2	—	0.013	
7	6 39 10 a.m.	Slight.	80	7.1	—	0.049	Accompanied by sound.
„	6 47 55 a.m.	*	40	7.3	—	0.013	
8	11 40 15 a.m.	*	60	11.0	—	0.010	
9	8 14 50 p.m.	Slight.	45	8.1	0.003	0.013	Sound heard toward S.
11	5 29 10 a.m.	*	80	22.4	—	0.010	
„	11 06 15 a.m.	*	60	?	—	Small.	Origin distant.
„	11 39 25 a.m.	*	75	?	—	0.006	Do.

Date.	Time of Occurrence.	Intensity.	Total Duration.	Duration of Prel. Tremor.	Max. Motion in		Remarks.
					Prel. Tremor.	Principal Portion.	
	December.						
	h m s		sec.	sec.	mm.	mm.	
11	2 41 20 p.m.	*	30	?	—	Small.	Origin distant.
12	5 01 45 a.m.	*	25	6.9	—	0.006	Sound only perceived.
14	5 48 30 p.m.	Slight.	50	8.4	—	0.016	Accompanied by sound.
16	11 25 36 a.m.	Do.	70	11.8	—	0.077	
"	1 26 50 p.m.	*	80	15.8	—	0.006	
17	10 58 00 a.m.	Slight.	70	9.4	—	0.004	
"	8 24 15 p.m.	*	50	8.0	—	0.011	
18	1 04 50 p.m.	*	Short.	Short.	—	Small.	Loud sound was perceived.
"	7 56 00 p.m.	*	Do.	Do.	—	Do.	Do.
19	4 10 30 a.m.	*	80	?	—	0.004	Origin distant.
21	2 09 20 a.m.	Slight.	45	6.7	—	0.010	Accompanied by sound.
"	5 20 30 a.m.	Do.	30	?	—	Small.	Origin distant.
"	8 16 08 a.m.	Do.	100	8.0	—	0.033	
23	7 57 40 a.m.	*	60	14.1	—	0.007	
"	11 38 05 a.m.	Moderate.	195	33.6	0.017	0.160	Accompanied by sound.
24	4 29 30 p.m.	*	50	17.5	—	0.010	
25	6 19 40 p.m.	Slight.	50	8.4	—	0.007	
"	6 42 50 p.m.	Do.	80	9.2	—	0.033	
26	3 40 20 a.m.	*	10	—	—	—	
"	6 45 00 a.m.	*	50	—	—	—	
"	11 04 30 a.m.	Slight.	35	7.0	—	—	
"	0 11 45 p.m.	Moderate.	240	12.0	—	0.138	Accompanied by sound.
"	2 38 25 p.m.	*	20	—	—	—	
"	7 10 20 p.m.	*	40	—	—	—	
27	0 50 50 p.m.	*	60	21.8	—	0.010	
"	9 06 30 p.m.	*	50	?	—	0.007	
28	2 03 25 a.m.	*	40	?	—	0.003	Origin distant.

Date.	Time of Occurrence.	Intensity.	Total Duration.	Duration of Prel. Tremor.	Max. Motion in		Remarks.
					Prel. Tremor.	Principal Portion.	
	December.						
	h m s		sec.	sec.	mm.	mm.	
28	4 03 40 p.m.	*	120	52.0	—	0.022	
29	6 59 30 p.m.	*	40	?	—	Small.	Origin distant.
„	7 02 40 p.m.	*	20	?	—	Do.	Do.
30	7 52 10 p.m.	*	80	9.6(?)	—	0.030	Do.

Typical Diagrams. Typical diagrams are reproduced in Pls. I to V, as follows.

Plate.	Figure.	Date.	Time of Occurrence.	Intensity.	Remarks.
<i>Sharp Local Earthquakes.</i>					
I	1	April 6	^{h m s} 9 29 10 p.m.	Moderate.	{ Loud sound heard 5 or 6 sec. before the shock.
	2	July 27	1 38 15 a.m.	Do.	Accompanied by loud sound.
	3	June 11	11 50 10 p.m.	Do.	Do.
	4	" 7	6 12 30 a.m.	Do.	Do.
	5	" 27	3 17 10 a.m.	Slight.	Accompanied by sound.
<i>Large Earthquakes.</i>					
II	6	September 21	10 00 55 p.m.	Moderate.	No sound.
	7	October 2	10 56 20 a.m.	Do.	Do.
<i>Small Local Shocks.</i>					
III	8	September 2	4 26 30 p.m.	Moderate.	Accompanied by loud sound.
	9	April 6	11 33 40 p.m.	Unfelt.	
	10	May 26	2 00 25 a.m.	Slight.	Accompanied by sound.
	11	September 20	4 22 10 p.m.	Do.	.. loud sound.
	12	October 2	7 47 10 a.m.	Unfelt.	
	13	September 19	10 38 30 p.m.	Do.	
<i>Earthquakes of some Distant Origin. (a)</i>					
IV	14	July 7	1 21 25 a.m.	Moderate.	No sound.
	15	November 1	2 01 50 p.m.	Do.	Do.
	16	June 12	5 17 30 p.m.	Do.	{ Sound heard 5 sec. before the shock.
	17	May 26	3 46 50 p.m.	Do.	{ Loud sound heard 3 sec. before the shock.
	18	October 10	1 49 20 p.m.	Slight.	

Plate.	Figure.	Date.	Time of Occurrence.	Intensity.	Remarks.
<i>Earthquakes of some Distant Origin. (b)</i>					
	19	July 7	^{h m s} 7 17 25 a.m.	Moderate.	Accompanied by sound.
	20	August 25	6 49 10 p.m.	Slight.	Do.
	21	June 7	{ 2 39 50 p.m. 2 40 20 „	{ Moderate. Slight.	Accompanied by loud sound.
V	22	July 7	10 38 00 a.m.	Unfelt.	
	23	October 10	5 10 55 a.m.	Do.	
	24	June 27	1 09 30 a.m.	Do.	
	25	September 2	3 48 25 p.m.	Do.	

The characteristics of a sharp local shock are the shortness of the duration of the preliminary tremor, and the occurrence of the maximum vibration of the latter and the principal portion at the commencement of each of the respective phases. In the cases of the four *moderate* earthquakes of April 6, July 27, and June 11 and 7, (Figs. 1 to 4, Pl. I), which were each accompanied or preceded by a loud sound, the duration of the preliminary tremor varied between 5.6 and 7.9 sec., the maximum double amplitude in the principal portion being 0.190 to 0.490 mm. In the *slight* earthquake of June 27 (Fig. 5, Pl. I), the duration of the preliminary tremor was 12.1 sec., the maximum motion being 0.183 mm.

The two earthquakes of Sept. 21 and Oct. 2, (Figs. 6 and 7, Pl. II), which were larger than those above mentioned were, according to the report of the observers, not accompanied by sound.

Of the six small local shocks whose diagrams are given in Pl. III, that on Sept. 2, (Fig. 8), was accompanied by loud sound and was moderate in intensity, although its maximum motion was only 0.094 mm; the preliminary tremor having lasted 13.1 sec.

The *slight* earthquakes on May 26 and Sept. 20, (Figs. 10 and 11), were also accompanied by sound, which was loud in the case of the second shock. Of the remaining three insensible earthquakes, (Figs. 9, 12, and 13), those on Oct. 2 and Sept. 19 were extremely small.

Of the four *moderate* earthquakes (PL. VI), whose origins were at some distance from Tsukuba, those on July 7 and Nov. 1, (Figs. 14* and 15), are reported as having been accompanied by no sound. The other two shocks, which happened on June 12 and May 26, were each preceded by loud sound. The slight earthquake on Oct. 10 (Fig. 18) was similar to, but much smaller than, that on May 26 (Fig. 17).

The diagram of the earthquake of July 7 (Fig. 19), which was accompanied by sound, presents an appearance of two shocks happening in succession, the motion being comparatively large in the preliminary tremor, which was of a long duration and lasted 62 sec. In fact, this earthquake has been reported by the observers at Tsukuba as two distinct ones, whose intensities were *slight* and *moderate* respectively. The diagram of the earthquake of Aug. 25 (Fig. 20), indicates the similar peculiarity still more markedly; the motion in the preliminary tremor, which lasted 99 sec., being not much smaller than that in the principal portion. This earthquake was also reported as two separate ones, each of which was *slight* and was accompanied by sound. The latter circumstance is very interesting, as it gives support to the view that the earthquake sound occurs not only in the preliminary tremor, but also in the principal portion. The two unfelt earthquakes on July 7 and Oct. 10, (Figs. 22 and 23), are much similar in character to

* The zero-position of the recording pointer of the instrument suffered some displacement during the shaking.

the two shocks above mentioned. Fig. 21 represents, on the other hand, a case of two really distinct earthquakes one of which was *moderate* and the other *slight*, happening in quick succession. Finally, the two earthquakes on June 27 and Sept. 2 are examples of shocks of somewhat distant origin, whose preliminary tremor is small.

Duration of the preliminary tremor. The relative frequencies of the different lengths of the duration of preliminary tremor less than 40 sec., measured in the cases of 329 earthquakes, were as shown in the following table

Duration of Prel. Tremor.		Number of Earthquakes.	Duration of Prel. Tremor.		Number of Earthquakes.
sec.	sec.		sec.	sec.	
0.0—0.9		9	20.0—20.9	3	
1.0—1.9		0	21.0—21.9	3	
2.0—2.9		2	22.0—22.9	4	
3.0—3.9		2	23.0—23.9	6	
4.0—4.9		4	24.0—24.9	3	
5.0—5.9		15	25.0—25.9	4	
6.0—6.9		29	26.0—26.9	0	
7.0—7.9		24	27.0—27.9	1	
8.0—8.9		36	28.0—28.9	2	
9.0—9.9		35	29.0—29.9	3	
10.0—10.9		21	30.0—30.9	5	
11.0—11.9		18	31.0—31.9	1	
12.0—12.9		13	32.0—32.9	3	
13.0—13.9		11	33.0—33.9	1	
14.0—14.9		11	34.0—34.9	1	
15.0—15.9		8	35.0—35.9	3	
16.0—16.9		9	36.0—36.9	3	
17.0—17.9		11	37.0—37.9	2	
18.0—18.9		9	38.0—38.9	0	
19.0—19.9		12	39.0—39.9	2	

The number of cases, in which the duration of the preliminary tremor was over 40 sec., is 24, as follows:—

Duration of the Prel. Tremor.	}	40 sec.	58 sec.
		40.2	60
		41	62
		41	62
		43	63
		46	65
		49.3	69
		50	79
		50	88
		52	95
		52	99
		54	114

As graphically illustrated in Fig. 26, Pl. VI, the duration of the preliminary tremor most frequently occurring was between 6 and 10 sec., the number of the corresponding earthquakes being equivalent to the two-thirds of all the others. The relation between the duration of the preliminary tremor and the corresponding frequency of earthquakes will be of course different for different places of observation.

Number of sensible shocks. The total number of the sensible shocks was 171, while that of mere sounds (not accompanied by perceptible earth movement) was 12, as follows.

Month.	Sensible and Insensible Eqkes.	Number of		
		Sensible Eqkes.	Mere Sounds.	Sensible Eqkes, accompanied by Sound.
I	24	12	2	10
II	31	17	5	18
III	24	14	0	13
IV	26	7	1	7
V	27	8	0	5
VI	50	15	0	14
VII	67	21	1	17
VIII	48	11	0	9
IX	49	15	0	14
X	57	18	0	9
XI	35	16	0	13
XII	49	17	3	12
Sum	487	171	12	141

Thus the number of the sensible earthquakes, (including the cases of mere sounds), was 183, so that such shocks occurred at Tsukuba on the average once nearly every two days. The number of the insensible shakings was 304.

Earthquake sounds. At Tsukuba, earthquake sounds are perceived very often, which may be likened to the noises of distant thunders or of a wagon passing over a wooden bridge, those like the rushing of winds being comparatively rare. The monthly numbers of the sensible shocks accompanied by sound, including the cases of sounds without sensible motion, are given in the last column of the above table. From the latter it will be seen that earthquake sounds occurred in 141 cases, or in 77% out of the 183 sensible shocks. It is possible that all of the latter, or nearly so,

are found to be accompanied by more or less sound, when very attentively observed.

There were 27 cases, in which the direction of the sound was noted, as follows:—

}	Sound heard toward the South	17 cases.
	,, South-West	9 ,,
	,, South-East.....	1 ,,

The resultant, or mean, direction was thus South-West by South. That the sounds were perceived as coming from this quarter may be due to the fact that the lower part of the southern slope of the mountain, where the town of Tsukuba is situated, is horse-shoe shaped and opens in the same direction to the low plane.

In a majority of cases the sound was first perceived, followed immediately or a few seconds later by the tremblings of the ground, as in the following examples.

Eqke of May 26.....	{	Duration of Prel. tremor=19.4 sec.
		Sound heard 3 sec. before the shock.
Eqke of June 12.....	{	Duration of Prel. tremor=18.4 sec.
		Sound heard 5 sec. before the shock.

It is probable that the commencement of the sound is generally at the same instant as that of the preliminary tremor, whose earlier part may often be insensible while the sound is perceptible. This explanation can not, however, be applied to the following two cases, provided the report of the observers be accurate:—

Eqke of April 6.....	{	Duration of Prel. tremor=6.7 sec.
		Sound heard 5 or 6 sec. before the shock.

Eqke of June 11..... { Duration of Prel. tremor=5.6 sec.
Sound heard 3 sec. before the shock.

In each of these two shocks, which were *moderate* in intensity, the motion at the commencement of the preliminary tremor was quite large and perfectly sudden. Hence it seems impossible that sound should be heard a few seconds prior to the arrival of the sensible motion, unless the vibrations of the ground giving rise to the sound phenomena form a sort of an *ultra* preliminary tremor and are so extremely minute that the seismograph used could give no visible trace. Such a supposition may not be entirely wrong, since there are cases of loud sounds hardly accompanied by any movement.

Earthquake sound and duration of preliminary tremor.

The numbers of sensible earthquakes and of those accompanied by sounds, for the different lengths of the preliminary tremor, are given in the following table.

Duration of Prel. Tremor.	Total Number of Sensible Earthquakes=e.	Eqkes accompanied by Sound*=s	Ratio: $\frac{s}{e}$
(i) sec. sec. 0—5.0	18	18	100 %
(ii) 5.1—10.0	77	66	86
(iii) 10.1—15.0	35	28	80
(iv) 15.1—20.0	20	16	80
(v) 20.1—25.0	5	4	80
(vi) >25.1	18	10	56
Sum: (i) to (v)	155	132	85

(* Including the cases of mere sound.)

Thus it will be observed that the sensible earthquakes of near origin of the duration of the preliminary tremor under 5 sec., were invariably accompanied by sound. The percentage number of the more distant shocks remained practically constant for the duration of the preliminary tremor between 5 and 25 sec., varying only between 86 and 80%, with the mean value of 85%. Even for the earthquakes of the duration of the preliminary tremor over 25 sec., the sound was by no means uncommon, the frequency amounting to 56%.

Distant earthquakes accompanied by sounds. Among the 183 sensible earthquakes, there were ten, which were accompanied by sounds, and the duration of whose preliminary tremor was longer than 25 sec., as follows.

Date.	Intensity.	Duration of Prel. Tremor.	Maximum Motion.
March 21	Slight.	^{sec.} 36.0	^{mm.} 0.020
June 10	Do.	36.4	0.042
July 7	Moderate.	62.0	0.173
Do. 9	Do.	29.3	0.150
August 25	Slight.	99.0	0.097
September 1	Do.	40.0	0.022
Do.	Moderate.	79.0	0.150
October 10	Slight.	39.0	0.038
November 27	Do.	31.3	0.037
December 23	Moderate.	33.6	0.160

In these 10 earthquakes, the duration of the preliminary tremor varied between 29.3 and 99.0 sec., which correspond respectively

to the epicentral distances of about 250 and 760 km; the maximum (EW component) motion in the principal portion varying between 0.020 and 0.173 mm. It is probable that even an earthquake at an epicentral distance of 1,000 km is able, when of a sufficient intensity, to produce sound phenomena at Tsukuba or any other district composed of hard rocks.

Earthquakes accompanied by loud sound. There were 35 cases in which the shock was accompanied by loud sound. The elements of motion in these earthquakes, arranged according to the length of the duration of the preliminary tremor, were as in the following table; the maximum movements in the preliminary tremor and the principal portion being denoted by 2a' and 2a respectively.

Date.		Duration of Prel. Tremor.	Intensity.	Max. Motion in Prel. Tremor = 2a'	Max. Motion in Princ. Portion = 2a
Jan.	25	sec. 0.0	Unfelt	mm. —	mm. (No. motion indicated)
Feb.	7	0.0	Slight	—	0.072
Oct.	4	(short)	Do.	—	Small
"	18	(Do.)	Unfelt	—	Do.
"	"	(Do.)	Unfelt	—	Do.
Aug.	20	2.5	Slight	—	0.022
Oct.	3	3.6	Do.	—	0.036
Nov.	19	4.5	Do.	0.003	0.044
July	12	4.7	Unfelt	0.002	0.004
April	30	4.9	Slight	—	0.036
"	27	5.4	Do.	0.004	0.021
Jan.	5	5.6	Do.	0.004	0.027
June	11	5.6	Moderate	0.066	0.230

Date.		Duration of Prel. Tremor.	Intensity.	Max. Motion in Prel. Tremor = 2a'	Max. Motion in Princ. Portion = 2a
		sec.		mm.	mm.
Oct.	6	5.9	Slight	—	0.007
June	7	6.1	Do.	0.032	0.190
July	26	6.2	Do.	0.016	0.073
Aug.	24	6.3	Moderate	0.044	0.770
April	6	6.7	Do.	0.093	0.490
July	29	6.9	Slight	—	0.060
June	6	7.0	Moderate	0.013	0.106
July	27	7.9	Do.	0.039	0.340
Sept.	13	7.4	Slight	0.003	0.017
„	20	8.4	Do.	0.002	0.038
April	13	9.0	Do.	0.018	0.064
Sept.	26	9.0	Do.	0.017	0.056
July	9	9.1	Do.	—	0.049
Oct.	3	9.1	Do.	0.014	0.026
„	10	9.2	Moderate	0.061	0.430
May	9	11.0	Do.	0.051	0.204
Nov.	24	12.8	Slight	—	0.041
Sept.	2	13.1	Moderate	0.006	0.094
June	26	13.3	Slight	0.008	0.039
„	7	17.7	Moderate	0.027	0.093
May	26	19.4	Do.	0.043	0.160
Oct.	10	39.0	Slight	—	0.038

Thus it will be seen that loud sounds occurred most frequently in the earthquakes, whose preliminary tremor lasted less than about 9 or 10 sec., corresponding to an epicentral distance of about 100 km. In three cases, the duration of the preliminary tremor was much longer, being from 17.7 to 39.0 sec. Again, of the 35

earthquakes tabulated above, 10 were *moderate*, 21 were *slight*, and the remaining 4 were unfelt shocks; each of the last having a very short preliminary tremor or apparently none whatever. The maximum motion in the preliminary tremor ($=2a'$) varied between 0.002 and 0.093 mm, and that in the principal portion ($=2a$) between 0.004 and 0.770 mm.* It is thus seen that the intensity of motion is not a necessary factor in the production of the sound phenomena, although a violent earthquake will always be accompanied by a very loud sound.

Ratio of maximum motion in preliminary tremor to that in principal portion. The maximum movements in the preliminary tremor and principal portion of the 7 sharp local shocks, whose diagrams are given in Pls. I and II, were as follows.

Date.		Duration of Prel. Tremor.	Max. Motion in Prel. Tremor $=2a'$.	Max. Motion in Princ. Portion $=2a$.	Ratio: $\frac{2a}{2a'}$
		sec.	mm.	mm.	
April	6	6.7	0.093	0.490	5.3
July	27	7.9	0.039	0.340	8.7
June	11	5.6	0.066	0.220	3.3
"	7	6.1	0.032	0.190	5.9
"	27	12.1	0.028	0.183	6.5
Sept.	21	9.7	0.250	0.860	3.4
Oct.	2	10.0	0.097	0.580	6.0
<i>Mean</i>					5.6

Thus the motion in the preliminary tremor increased generally

* Excepting a few cases in which the motion was immeasurably small.

with the strength of the shaking and was on the average $1/5.6$ of that in the principal portion. Hence it is likely that a violent destructive shock of near origin begins abruptly with quite large vibrations, so that its preliminary tremor may be much stronger than the principal portion of an ordinary earthquake.

In the following table, I give the $2a'$ and $2a$ in the 19 earthquakes of moderate intensity, whose duration of the preliminary tremor was under 20 sec. and whose absolutely greatest motion ($2a$) was over 0.1 mm; the shocks being arranged according to the magnitude of the latter element of motion.

Date.		Duration of Prel. Tremor.	Max. Motion in Prel. Tremor = $2a'$.	Max. Motion in Princ. Portion = $2a$.	Ratio: $\frac{2a}{2a'}$
		sec.	mm.	mm.	
Aug.	24	6.3	0.044	0.780	17.7
Oct.	10	9.2	0.061	0.430	7.0
„	14	5.7	0.044	0.240	5.5
Jan.	26	11.0	0.028	0.220	7.9
Sept.	24	7.8	0.031	0.210	6.8
May	9	11.0	0.051	0.204	4.0
June	18	13.2	0.023	0.190	8.3
Nov.	2	12.9	0.073	0.190	2.6
June	12	18.4	0.054	0.190	3.5
<i>Mean</i>					7.0
Feb.	17	14.1	0.027	0.180	6.7
March	4	9.0	0.022	0.170	7.7
May	26	19.4	0.043	0.160	3.7
April	24	9.0	0.017	0.153	9.0

Date.		Duration of Prel. Tremor.	Max. Motion in Prel. Tremor =2a'	Max. Motion in Princ. Portion =2a	Ratio: $\frac{2a}{2a'}$
		sec.	mm.	mm.	
Sept.	3	10.6	0.012	0.150	12.5
Feb.	7	17.0	0.036	0.120	3.3
July	19	9.3	0.022	0.120	5.4
Oct.	19	9.8	0.060	0.120	2.0
July	23	19.0	0.031	0.107	3.4
June	6	7.0	0.013	0.106	8.1
<i>Mean</i>					6.2

Dividing the 19 earthquakes tabulated above into two groups, of $2a > 0.19$ mm and of $2a < 0.18$ mm, the average values of the ratio $2a/2a'$ come out to be 7.0 and 6.2 respectively; the variation of this ratio with the $2a$ being apparently not significant. The mean value of this ratio deduced from the preceding tables is 6.3.

Finally, confining our attention to those sensible earthquakes, which were not accompanied by sound, the mean value of the ratio of $2a/2a'$ is found to be 5.7. This is not materially different from the mean value, namely, 7.0, of the corresponding quantity for those shocks accompanied by loud sound (page 35).

Least limit of sensible motion. In the sensible earthquakes, unaccompanied by sound, the maximum motion $2a$ was usually greater than 0.013 mm, there being only three cases in which it was less than this limit. With the earthquakes accompanied by sound, however, the limit of sensible motion was still lower, due probably to the predominance of quick vibrations in

these shocks; there being 14 cases in which the maximum motion $2a$ was less than 0.01 mm, as follows:—

mm	Number of Eqkes.
$2a = 0.010$	3
$2a = 0.009$	1
$2a = 0.008$	2
$2a = 0.007$	5
$2a = 0.006$	1
$2a = 0.004$	1
$2a = 0.003$	1

Making an allowance for the possible error in the measurement of very small movements, and provisionally excluding the last three cases, we may take the double amplitude of **0.007** mm as the limit of sensible vibration, the EW component motion alone being taken into account. Assuming the corresponding NS component to be of an equal range, the resultant double amplitude of the sensible motion would be about **0.01** mm. This latter value is to be regarded as the lowest limit of the earthquake motion which is intense enough to be felt without instrumental aid by people living in wooden houses at a quiet rocky district, where the earth vibrations are rapid.

The result here obtained is in accordance with that relating to the small vibrations of the ground caused artificially by an oil engine, etc. (See my paper, A Horizontal Tremor Recorder, in the *Publications*, No. 18). For Tokyo, the intensity of the lowest limit of the sensible motion was found to be an acceleration of 17 mm per sec. per sec. This is to be regarded as defining the feeblest earthquake motion sensible to people living in a large city or some other place where there is much disturbances arising

from traffic, the working of steam engines, dynamos, etc. (See the *Publications*, No. 11.)

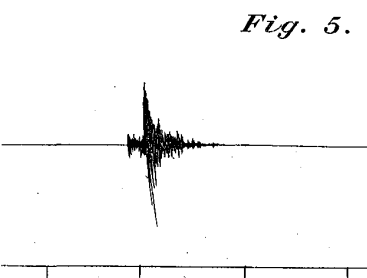
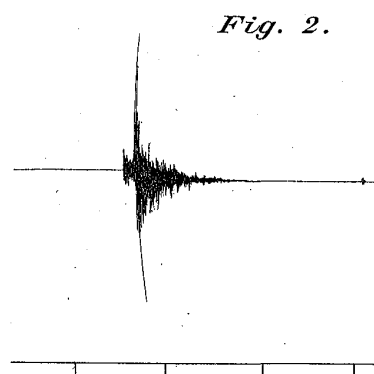
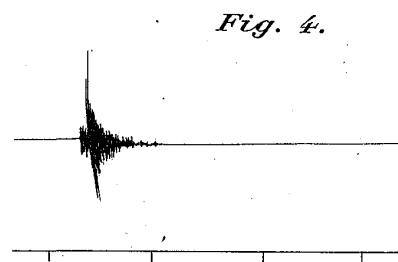
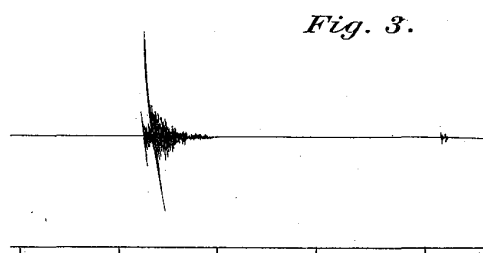
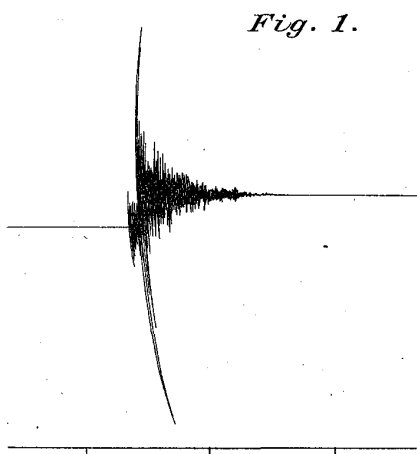
Conclusion. One of the principal objects in making the seismographic observations at Tsukuba was the comparison of the results there obtained with those simultaneously obtained in Tokyo and Mito, to determine thereby the accurate positions of the origins of the different local shocks, and also the relation between the epicentral distance and the duration of the preliminary tremor for near earthquakes. Further discussions on the Tsukuba observations in these connections are reserved for a future occasion. The instrumental study of the minute vibrations giving rise to sound phenomena is of course very important.

Tokyo, March 1908.

Earthquake Observation on Mount Tsukuba.

EW Component. Multiplication=90.

Time : 1 interval=1 minute.



- | | | |
|---------|--------------------------|---|
| Fig. 1. | April 6; 9h 29m 10s P.M. | } Moderate. Loud Sound heard
5 or 6 sec. before the shock. |
| „ 2. | July 27; 1 38 15 A.M. | |
| „ 3. | June 11; 11 50 10 P.M. | Do. |
| „ 4. | „ 7; 6 12 30 A.M. | Do. |
| „ 5. | „ 27; 3 17 10 A.M. | Slight. Accompanied by sound. |

Earthquake Observation on Mount Tsukuba.

EW Component. Multiplication=90.

Time : 1 interval=1 minute.

Fig. 6.
Sept. 21:10^h00^m55^s Pm

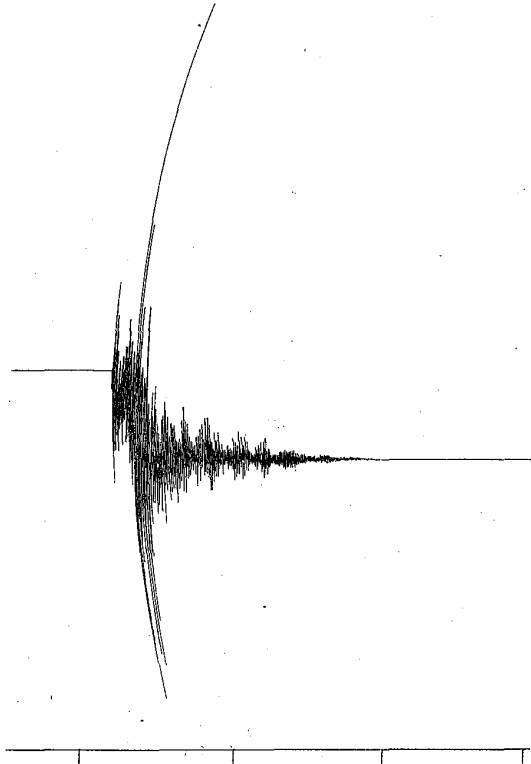
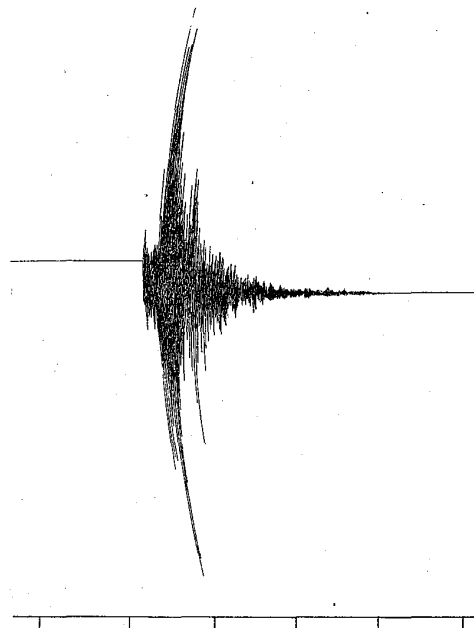


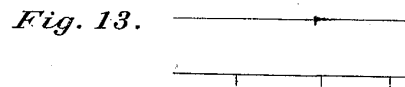
Fig. 7.
Oct. 2:10^h56^m20^s Am.



Earthquake Observation on Mount Tsukuba.

EW Component. Multiplication=90.

Time : 1 interval=1 minute.



- Fig. 8. Sept. 2; 4h 26m 30s P.M. *Moderate.* Accompanied by loud sound.
 „ 9. April 6; 11 33 40 P.M. *Unfelt.*
 „ 10. May 26; 2 00 25 A.M. *Slight.* Accompanied by sound.
 „ 11. Sept. 20; 4 22 10 P.M. *Slight.* Accompanied by loud sound.
 „ 12. Oct. 2; 7 47 10 A.M. *Unfelt.*
 „ 13. Sept. 19; 10 38 30 P.M. *Unfelt.*

Earthquake Observation on Mount Tsukuba.

EW Component. Multiplication=90.

Time: 1 interval=1 minute.

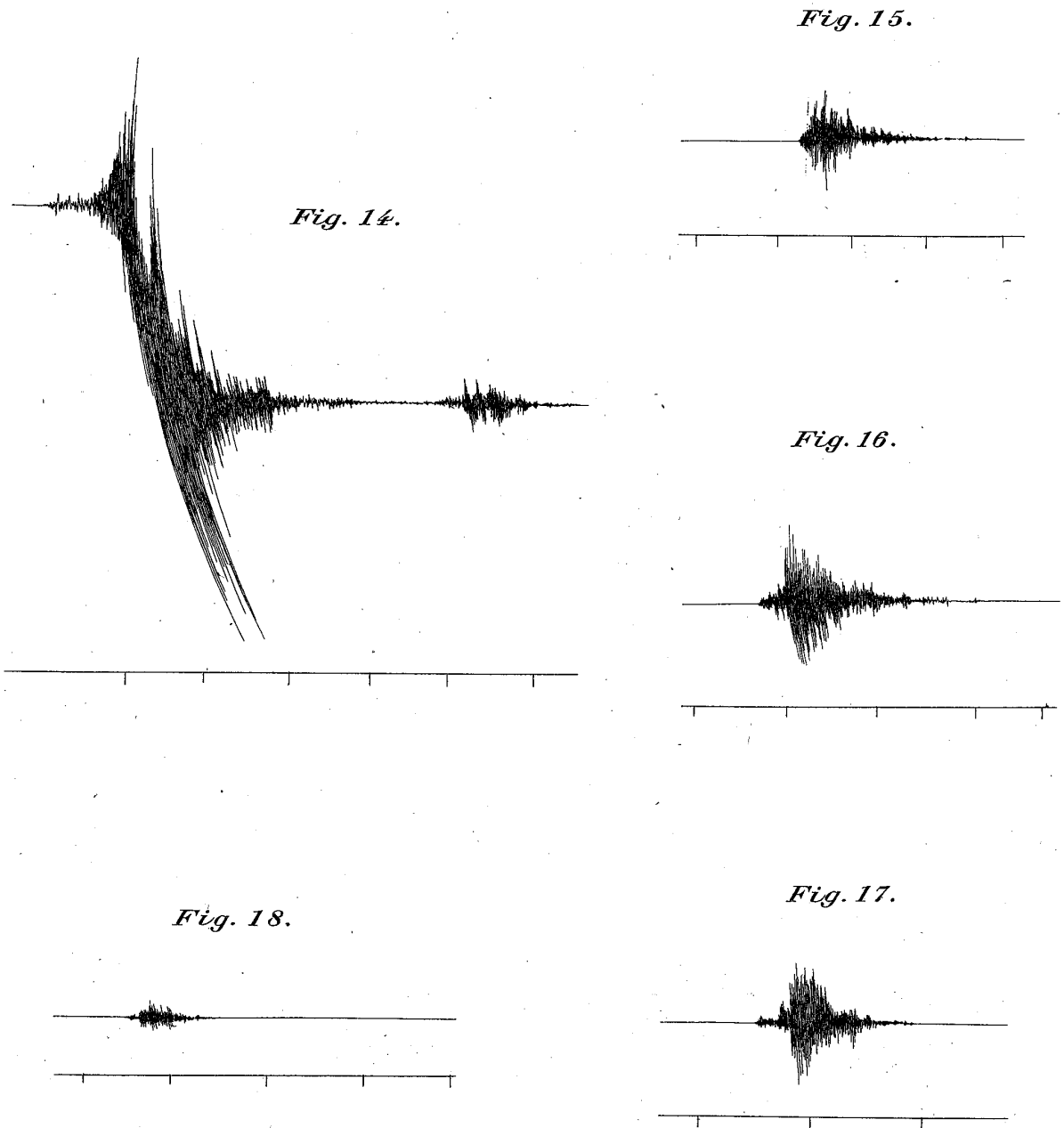


Fig. 14. July 7; 1h 21m 25s A.M. *Moderate.* No sound.
 „ 15. Nov. 1; 2 01 50 P.M. *Moderate.* No sound.
 „ 16. June 12; 5 17 30 P.M. { *Moderate.* Sound heard
 { 5 sec. before the shock.
 „ 17. May 26; 3 46 50 P.M. { *Moderate.* Loud sound heard
 { 3 sec. before the shock.
 „ 18. Oct. 10; 1 49 20 P.M. *Slight.*

Earthquake Observation on Mount Tsukuba.

EW Component. Multiplication=90.

Time : 1 interval=1 minute.

Fig. 19.

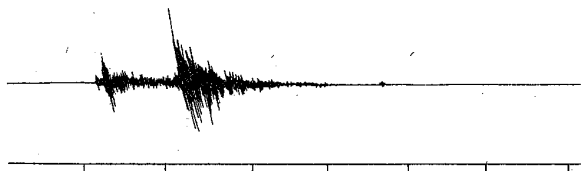


Fig. 22.



Fig. 20.

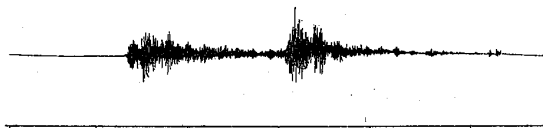


Fig. 23.

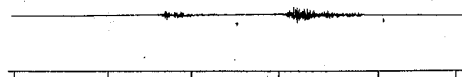


Fig. 24.



Fig. 21.

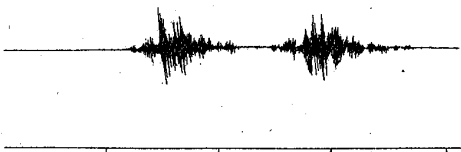


Fig. 25.



- | | | | | | |
|----------|----------|------------|------|-------------|----------------------------|
| Fig. 19. | July 7; | 7h 17m 25s | A.M. | Moderate. | Accompanied by sound. |
| „ 20. | Aug. 25; | 6 49 10 | P.M. | Slight. | Accompanied by sound. |
| „ 21, | June 7; | { 2 39 50 | P.M. | { Moderate. | Accompanied by loud sound. |
| | | { 2 40 20 | „ | { Slight. | |
| „ 22. | July 7; | 10 38 00 | A.M. | Unfelt. | |
| „ 23. | Oct. 10; | 5 10 55 | A.M. | Do. | |
| „ 24. | June 27; | 1 09 30 | A.M. | Do. | |
| „ 25. | Sept. 2; | 3 48 25 | P.M. | Do. | |

Fig. 26. Relative Frequencies of the Earthquakes of different lengths
of the Duration of the Preliminary Tremor.

x = Duration of the Preliminary Tremor, in second.

y = Number of the Earthquakes, the duration of whose preliminary tremor is equal to x.

