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On Milne Horizontal Pendulum Seismograms obtained at Hongo, Tokyo.

BY

A. IMAMURA, *Rigakushi,*

Extraordinary Member of the Imperial Earthquake Investigation Committee.

I. Introduction.

As a work of the Imp. Earthq. Inv. Comm., the present writer installed one of Milne H. P. Seismographs at the ground of Tokyo Imp. University, and started it on the summer of 1899; the result of observation having been reported from time to time to the Seismological Comm. of the British Association.

The horizontal pendulum is oriented to write *E. W.* motion, and stands on a brick pier of a height of 145 cm., of which the lower part measuring 60 cm. is imbedded in the ground and has a concrete footing of a thickness of 30 cm. The record-receiver stands also on the same pier which is lowered at this part by 30 cm. from the face where the pendulum stands. The pier has double coverings, of which the inner is metallic and the outer consists of wooden walls with metallic roof. The latter has a magnitude of $1{\cdot}5 \times 1{\cdot}8 \times 2{\cdot}0$ c.m.

As it is to be expected from such construction, the pendulum boom has nightly been disturbed during the colder months by so-called air current or air tremor. Several efforts have been made to suppress the cause of disturbance, but they were in vain. At present, the disturbance is lessened in some measure by putting a bad conductor of heat between the inner and outer coverings, which prevents sudden radiation of internal heat.

There are two other causes which sometimes obscured our seismograms. These are *tremors*, or quick small vibrations, and *pulsatory oscillations* or slow movements. Th former, which generally appear in sunny morning, mostly for an hour or two, has often been mistaken for real earthquake. Thus eqke No. 279 was one of the quick movements, for which I have estimated the duration of preliminary tremor and other characteristics. I have recently examined the phenomenon respecting this tremor further, and obtained the result that it was, in most cases, caused by quick stroke of an engine working at a distance of about 140 metres from the instrument.

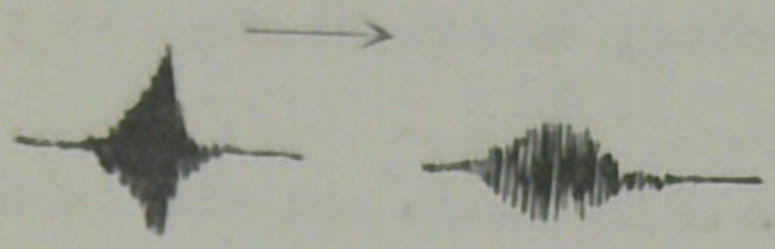
The pulsatory oscillation, of which a discussion has been given by Prof. Ōmori,[1]; obscured often the preliminary tremor and end portion of our seismogram, whilst in Omori's H.P. seismograms earthquake motion and pulsatory oscillations can be separated from each other on account of the difference of vibration period.

Next I proceed to discuss the behavior in relation to distant earthquake of our Milne H.P. seismograph, whose pendulum boom has been adjusted to have a free vibration period of 15 sec.

The instrument, which gives many important characters of earth movement, is sometimes affected into twofold errors; firstly, to write earth waves of a period near that of the pendulum boom exaggerated, and secondly, to write earth waves of long period (say 30 sec. or more) diminished. A full discussion has been given in the *Report* (Japanese) of the Earthquake Inv. Comm., No. 35; I will here give only a short sketch for the sake of reference.

Before proceeding further, let us explain the occurrence in the photograms of what I call *diagramatic maxima*. Those who have dealt with a Milne H.P. seismograph would scarcely fail to find in the diagrams of large earthquakes the movements increasing their magnitude slowly and gradually as in the annexed figure. Such diagramatic

1. Dr. Omori:—the *Publications*, No. 5 (pp. 51–57), and No. 13 (pp. 81–86).



maxima are also sometimes to be found in the seismograms of Omori H.P. seismograph, being very rare when the period of free oscillation of the pendulum is made larger than that of the earth movement (say 40 sec.). These maxima are, on the other hand, frequent in Milne H.P. seismograms, so that the phase of the absolute maximum, which is regarded by Prof. Milne as being of a great importance in the investigation of the transit velocity of the seismic waves and other characters, frequently coincides with one of these maxima. The latter which are most frequent in, or near, the sixth phase[1] of the earthquake motion are sometimes found even among the preliminary tremor and obscure the distinction between the second and third phases. Thus, for instance, in the Guatemala earthquake of April 19, 1902, the phase recorded at 3h 36 m 0 s in the register of the Cape of Good Hope, and that at 3 h 39 m 0 s in the Wellington register was evidently each one of these diagramatic maxima.

The object of the following notes on these diagramatic maxima, assumed to be essentially due to the proper oscillations of the pendulum boom itself, is to compare the amplitudes of waves in the seismograms given by Milne's apparatus with those given by Omori's mechanically registering Horizontal Pendulum Seismograph, and also to study the nature of the principal movements whether they consist of tilts or of horizontal motion. Omori's E.W. H.P. seismograph taken for comparison, which is one of the instruments set up in the "Earthquake-proof House," at Hongo, had a period of free oscillation of 30 sec.; 1″ tilt of the ground corresponding to 9·2 mm. on the diagram. On the other hand, the photographic register had the period of 15 sec., so that a tilt of 1″ amounts to 1·7 mm. on the record. Thus the ratio of amplitudes of the identical waves in the mechanical register and the photographic one should be 100 : 19, if the waves consisted of tilts. If, however, the recorded waves be supposed to be horizontal ones, this ratio turns out to be 100 : 67; the mechanical and

1. This corresponds to Dr. Omori's *4th phase of principal portion.*

the photographic registers having respectively 10 and 6·7 times magnifications.

Let us first compare the amplitudes of the initial and the quick period waves of the principal motion in the two kinds of seismograms, as these waves can easily be identified and ought to be comparatively free from the instrumental errors. Besides 23 earthquakes of comparatively near origin, the following eight distant ones have been taken for examination :—

Eqke. No.	Origin.	Date.
1	Smyrna.	Sept. 20, 18 9.
2	Ceram (Java).	,, 29, ,, .
3	Javan district.	Oct. 19, ,, .
4	Mexico.	Jan. 20, 1900.
5	Javan district.	March. 9, ,, .
6	Phillipine.	Oct. 7, ,, .
7	Off the S.W. coast of Alasca.	,, 9, ,, .
8	Javan district.	Nov. 12, ,, .

The result is that the average ratio of the amplitude in the seismograms from the Omori H.P. to that from the Milne H.P. is 100 : 67, which agrees fairly well with the ratio when the recorded motion is supposed to be horizontal. Dividing these earthquakes into two groups according to the distance of the origin, we find average ratios of 100 : 63 and 100 : 69 for the earthquakes whose preliminary tremors were respectivery longer, and shorter, than 3 min. For the earthquakes of distant origin, the periods of waves taken for comparison were generally long, and consequently the ratio is liable to turn out less than the real value, as the photographic register is less sensitive for such waves than the mechanical one. The ratio comes out, however, to be far greater than the value which would be obtained if the earth movements consisted of tilts.

Let us next compare the amplitudes of diagramatic maxima. Of the 15 earthquakes taken for the examination, six earthquakes,

namely, Nos. 1–6 in the above table, gave large seismograms. As some of these earthquakes indicate several maxima in their seismograms, the waves taken into account amounted to 23 in all. The result of the comparison is that the waves in the photograms were on average 3·8 times greater than the corresponding ones in the mechanical registers. This fact is apparently contradictory to the supposition either of horizontal movement or of tilt, and must therefore be explained in another way. To ascertain some possible instrumental errors, I examined thoroughly the diagrams given by the Omori H.P. seismograph, which showed, whenever the maxima occur in the registers of the Milne H.P. seismograph, for a few minutes, waves of a period of about 15 sec., which is equal to that of free oscillation of the boom in the latter instrument. In other words, the diagramatic maxima are the results of the synchronization of the oscillations of the pendulum boom with earth movements.

According to the recent investigation of Prof. Omori on the period of vibration in the different stages of the earthquake motion, the waves of a period of 15 sec. occur mostly in the sixth phase or near it, the result being to give rise in the photograms to the diagramatic maxima. In fact, the apparently largest waves are mostly found in, or near, the 6th phase, and these may possibly correspond to the *large waves* in Prof. Milne's investigation, their transit velocities being roughly equal to each other.

The second source of errors, to which the instrument is liable to fall, is to write long period waves diminished. Thus in the case of the Ceram (Java) earthquake of Sept. 29th, 1899, the initial principal phase appeared in the mechanical register as a motion of 16·5 mm. and of a period of 57 sec., while in the photographic register it was a motion of only 2·2 mm. In the Guatemala earthquake of April 19th, 1902, the mechanical register gave the amplitudes of 4·1 mm., 4·4 mm., and 14·0 mm. as the maxima in the first and second preliminary tremors and the earlier part of the principal portion respectively, whilst these appeared in the photographic register as motions

of 0·8 mm., 2·4 mm., and 1·0 mm. It is to be remarked that the waves in these different stages had the following periods 6·9 sec., 16·3 sec., and 13·1 sec. in the 1st preliminary tremor, 8·6 sec., 27·8 sec., and 28·3 sec. in the 2nd preliminary tremor, and 38·7 sec., 33·3 sec., and 26·7 sec. in the earlier part of the principal portion.[1] Again in the photogram of the Guatemala earthquake of Sept. 23rd, 1902 (Fig. 5), the phase at 20 h 47·8 m which is the maximum in the record may be mistaken to have been some phase of the principal portion, but it was really a phase of the preliminary tremor. In fact, the principal portion commenced at 21 h 4·0 m, having been indicated as minute waves in the photographic register. Comparing the seismograms given by the two instruments (Figs. 5–6), the above statement will be verified; besides it will be seen that the vibration period of waves of the preliminary tremor was nearly equal to that of the free oscillation of our pendulum instrument, and that in the principal portion the period was very large.

It is hereby to be noted that a proper consideration of the instrumental behavior before mentioned is necessary in distinguishing the different phases, especially in the register of large distant earthquake; otherwise we shall fall into an error in the discussion of the transit velocities and consequently of the path along which the different phases of the earthquake motion are propagated.

As the first condition of a seismograph for the observation of distant earthquakes, the period of free oscillation of the pendulum must be large enough to record correctly the slow undulations, forming the initial phase of the principal portion, whose average period is, according to Prof. Omori, about 30 sec. The second condition is to drive the record-receiver sufficiently quick to record the waves of a period of a few seconds distinctly.[2] As our Milne H.P. seismograph

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1. See Dr. Omori: Horizontal pendulum observation &c., the *Publications*, No. 13, p.p. 107–108.

2. See also Dr. Omori: On seismic instruments. *I er Bericht der I Intern. seismologischen Konferenz.*

does not possess these conditions, it is inconvenient for the purpose of investigating the nature of the earthquake waves accurately ; yet if we bear in mind the remarks above made, we may deduce some important results respecting the general character of the earth movements.

II. List of earthquakes.

The following list contains the result of observation of 303 earthquakes which occurred from July 1899 to Dec. 1902, all of them, with five exceptions, having been registered with our Milne H.P. seismograph.

The earthquake Nos. in the list are the same as those in the Tokyo registers in Milne's Circulars Nos. 1–6, the newly added earthquakes being reckoned in dashed numerals. The time of arrival of P_1 in the list is the same with the time of commencement in the Tokyo registers, but in certain cases correction has been given to the latter as a result of comparative study of the seismograms given by Milne's and Omori's H.P. instruments. The phase P_5, which is called by Prof. Omori the *third* or *quick period phase* of the principal portion, is in most of near earthquakes coincident with the maximum phase, but it is not necessarily so, especially in cases of distant earthquakes. Whenever the distinction between the 1st and 3rd phases of principal portion was not clear, I have put the data relating to this ambiguous case in the column headed P_5. *Amplitude* is used in the meaning of one-half of the total range in the record. Assuming the earth movements to consist of impulsive horizontal motion, the amplitude in the list divided by 6·7 represents the natural magnitude ; but if they are assumed to be tilts, the recorded amplitude divided by the factor 1·7 represents the tilt in seconds or in decimals of second.

Hereby it is to be remarked that the earthquakes given in the list do not include a few which were missed out of register on account of stopping of the clock, exhausting of the lamp, want of sensitive paper, or accidental object on the pendulum boom, while many

seismograms have been masked by air current, pulsatory oscillations, or larger earthquakes of longer duration.

In the list, the following abbreviations are used:—

a. c.....for air current or *air tremor*.

p. o.....for pulsatory oscillations.

Earthquake Nos. printed with fat letters relate to the more important seismograms whose special description is given in Chapter III.

LIST OF 298 EARTHQUAKES OBSERVED AT HONGO, TOKYO, JULY 1899 TO DEC. 1902, WITH MILNE'S HORIZONTAL PENDULUM SEISMOGRAPH.

No.	Date.	Time of occurrence.*		Amplitude.†		Total duration.
		P_1	P_3	P_1	P_3	
1899.						
1	July 24	1h 23.3m	h— m	Slight.	—mm	1h 29m
2	Aug. 26	5 1.3	5 1.5	Do.	0.55	10
3	Sept. 4	0 31.2	0 57.3	0.1mm	0.5	1 20
4	„ 9	2 2.8	2 4.0	0.5	3.6	49
5	„ 11	11 37.1	—	Slight.	—	Short.
6	„ 13	—	14 8.1	—	0.75	Obscured by a.c.
7	„ 20	2 24.5	3 0.0	—	0.7	2 50
8	„ 23	11 —	—	—	—	Obscured by p.o.
9	„ 29	17 11.6	17 28.6	0.1	4.2	2 30
10	Oct. 4	9 9.0	9 12.8	0.1	1.4	1 10
11	„ 10	—	10 18.3	—	8.0	Obscured by a.c.
12	„ 19	9 29.1	9 46.3	0.2	3.4	1 50
13	„ 22	4	27.9	.35		3
14	Nov. 2	6	9.0	1.2		6
15	„ 7	1 5.5	1 6.5	Slight.	0 35	4
16	„ 10	—	23 28.9	Slight.	0.65	6
17	„ 11	22 41.8	22 47.0	Slight.	0.6	54
18	Dec. 3	6	32.9	0.6		4
19	„ 17	3	40.3	0.3		3
20	„ 17	6	35.0	0.3		3
21	„ 20	23	26.4	0.9		4
22	„ 30	10 14.8	10 20.4	Slight.	0.75	37
1900.						
23	Jan. 3	4	43.4	0.35		3
24	„ 11	9 14.5	9 25.8	Slight.	3.2	1 30
25	„ 15	5 5.8	5 7.2	Do.	2.0	8
26	„ 16	3 36.1	3 37.1	Do.	.65	7.5
27	„ 16	—	15 14.8	Do.	4.0	5
28	„ 18	7 46.7	7 49 0	—	.35	25
29	„ 20	6 47.2	7 34.6	Slight.	1 0	2 30
30	„ 21	—	18 29.2	—	3.5	7

* Time is expressed in Greenwich Mean Time.

† Amplitude means one-half of the total range in the *record*.

No.	Date.	Time of occurrence.		Amplitude.		Total duration.
		P_1	P_3	P_1	P_3	
		1900.				
31	Jan. 24	$5^h\ 17.8^m$	$5^h\ 21.8^m$	—mm	1.5mm	Obscured by a.c.
32	„ 30	—	3 57.5	—	.45	3
33	Feb. 2	8 5.5	8 8.0	0.1	.5	10
34	„ 3	4 24.7	4 38.2	Slight.	0.3	45
35	„ 13	2 11.5		.35		4
36	„ 13	4 27.9	4 30.8	0.1	2.3	22
37	„ 17	3 54.0		1.2		7
38	„ 17	6 21.5		.35		3
39	„ 25	—	22 20.6	—	1.7	Obscured by a.c.
40	March 4	2 58.1		1.3		.5
41	„ 4	6 18.2		0.1		1.5
42	„ 4	7 29.8		0.1		1.8
43	„ 9	2 36.0	2 54.3	0.1	1.1	>1 10
44	„ 12	1 34.6	1 35.4	.4	6.0	>1 0
45	„ 14	14 55.6		0.7		7.8
46	„ 21	15 55.8	15 56.5	Slight.	0.6	6.7
47	„ 26	8 32.4		1.8		7
48	„ 26	8 44.9		0.5		3.5
49	„ 26	11 52.4		1.1		6
50	April 14	22 49.4	22 49.8	Slight.	5.4	13
51*	„ 24	6 5.5	6 6.5	—	10.3	10
52	„ 24	23 19.3	23 27.7	0.2	2.7	2 0
52′	May 11	—	—	—	—	—
53	„ 20	23 29.2	23 29.4	Slight.	2.1	1.7
54	„ 22	22 14.5		0.9		1.2
55	June 2	1 12.2	1 13.6	Slight.	0.3	8
56	„ 2	21 39.7	21 44.8	0.2	1.2	1 20
57	„ 23	6 46.8	6 48.2	Slight.	0.3	6.7
58	„ 25	6 47.3		3.2		7
59	„ 25	12 12.2	12 12.5	Slight.	0.5	2.6
60	„ 29	0 56.0		0.4		3

* Probably not earthquake.

No.	Date.	Time of occurrence.		Amplitude.		Total duration.
		P_1	P_5	P_1	P_5	
		1900				
61	June 29	23^h 29.1^m		0.3^{mm}		0^h 3^m
62	July 7	1^h 46.5^m	2^h 46.8^m	Slight.	0.7^{mm}	1.3
63	,, 8	2 46.4	2 46.7	Do.	3.3	7.5
64	,, 22	9 18.7	9 20.1	Do.	0.2	5
65	,, 22	13 24.3	13 24.7	Do.	1.8	12
66	Aug. 5	4 20.7	4 21.5	0.4	14.8	1 20
67	Sept. 2	17	55.0	6.5		Probably not earthquake.
68	,, 14	15	48.3	0.2		2
69	,, 24	3 35.4	3 37.7	0.6	1.2	12
70	,, 30	34.4		6.0		Nature doubtful.
71	Oct. 7	21 9.2	21 25.4	6.2	3.0	2 15
72	,, 8	5	40.4	0.2		6
72′	,, 8	9 2.3	—	0.2	—	1 30
73	,, 9	12 37.0	12 56.0	0.6	2.2	3 20
74	,, 11	19	2.7	0.5		1.5
75	,, 12	23 0.1	23 1.8	Slight.	1.0	13.7
76	,, 15	4 4.2	4 4.6	Do.	0.3	4
77	,, 20	18 33.6	18 47.8	Do.	0.5	1 0
78	Nov. 5	5	9.4	0.9		7
79	,, 5	7 41.3	7 41.5	0.2	38.0	E.p. interfered by eqke No. 80.
80	,, 5	8	19.7	8.5		> 14
81	,, 5	10 38.1	10 38.7	Slight.	0.4	5.5
82	,, 5	12 17.8	12 18.3	Do.	0.4	7
83	,, 5	12 35.1	12 35.4	Do.	0.4	7
84	,, 5	12 45.3	12 45.9	Do.	0.4	9
85	,, 6	9 13.3	9 15.8	Do.	0.2	9
86	,, 9	2 30.7	2 31.5	Do.	0.7	5
87	,, 9	17 54.9	17 56.1	0.6	36.0	3 0
88	,, 12	1 14.9	1 30.4	0.2	3.0	2 40
89	,, 14	7 31.3	7 31.8	Slight.	0.3	4
90	,, 14	15 3.0	15 3.4	Do.	0.6	4

No.	Date.	Time of occurrence.		Amplitude.		Total duration.
		P_1	P_5	P_1	P_5	
			1900.			
91	Nov. 14	21h 36.8m	21h 37.7m	0.3mm	2.2mm	1h 20m
92	„ 15	4 10.5	4 11.5	Slight.	1.7	4
93	„ 15	10 41.5	10 42.7	Do.	0.5	23
94	„ 15	13 53.3	13 53.6	Do.	0.7	2.5
95	„ 19	4 34.6	4 35.3	Do.	0.6	20
96	„ 19	13 57.9	13 59.9	Do.	0.9	9
97	„ 20	9 20.0	9 20.5	Do.	0.2	3.5
98	„ 24	5 4.2	5 4.9	Do.	0.3	3.8
99	„ 24	7 58.9	8 4.2	0.7	2.5	2 40
100	„ 27	12	19.0	0.2		4.5
101	Dec. 1	3 33.0	3 33.4	Slight.	0.5	3
102	„ 3	14 6.9	14 7.9	0.6	3.0	1 0
103	„ 7	7 12.2	7 16.0	0.1	0.8	1 0
104	„ 20	8 27.5	8 31.0	Slight.	1.0	10
105	„ 21	—	12 28.6	—	0.9	Obscured by a.c.
106	„ 25	5 7.6	5 11.8	1.2	30.0	2 30
107	„ 25	7	59.2	0.4		2.7
108	„ 25	11 4.8	11 5.2	Slight.	1.3	7
			1901.			
109	Jan. 4	16 51.9	16 53.4	Slight.	0 3	7
110	„ 6	—	7 49.5	—	3.0	Obscured by a.c.
111	„ 7	5 21.6	5 22.6	Very slight.	0.7	12
112	„ 13	5	47.1	0.4		4
113	„ 13	22 41.5	22 44.2	0.4	5.0	1 20
114	„ 14	7	27.9	0.3		3
115	„ 15	6	46.0	0.3		2
116	„ 16	2 1.3	2 2.0	Very slight.	1.0	20
117	Feb. 15	8 3.5	8 19.0	Very slight.	1.6	55
118	„ 18	0 25.8	0 26.8	0.3	2.1	40
119	„ 20	9 53.8	10 3.4	0.1	0.6	1 0
120	March 4	8	58.2	0.5		6.5

No.	Date.	Time of occurrence.		Amplitude.		Total duration.
		P_1	P_5	P_1	P_5	
			1901.			
121	March 6	$6^h\ 55.0^m$		0.7^{mm}		3^m
122	„ 18	$23^h\ 56.9^m$	$23^h\ 58.6^m$	—	0.8	15
123	„ 20	3 33.8		0.8		13
124	„ 21	0 27.2		0.8		2
125	„ 23	14 22.3	14 29.2	0.4	1.5	1 20
126	April 5	22 33.3	22 35.6	0.2	0.6	40
127	„ 5	23 34.0	23 38.8	0.3	15.0	2 35
128	„ 7	18 15.0	18 16.2	Slight.	2.0	35
129	„ 22	18 9.5		15.0		11.
130	May 3	1 43.8		0.5		3.
131	„ 13	—	20 10.6	—	14	15
132	„ 14	6 51.0	6 54.0	0.1	2.8	2 0
133	„ 16	3 29.8		0.5		2
134	„ 16	4 54.5		0.3		18
135	„ 16	6 21.8	6 22.5	—	1.3	?
136	„ 22	2 8.1		0.7		4
137	„ 23	1 45.0		1.2		6
138	June 6	8 20.9		0.3		2
139	„ 12	1 44.8		0.6		2.3
140	„ 13	3 23.4	3 31.8	Slight.	0.9	2 0
141	„ 13	18 40.2		0.6		3
142	„ 13	21 54.7		0.4		3.2
143	„ 14	13 14.1		0.5		3.8
144	„ 14	18 39.7		0.9		3
145	„ 15	0 43.1		0.6		6.8
146	„ 15	9 33.8		0.2		6
147	„ 21	8 16.1		0.5		3.2
148	„ 21	9 23.8		0.4		3.6
149	„ 21	13 17.9		0.4		2.5
150	„ 25	4 26.8		0.6		4

No.	Date.	Time of occurrence.		Amplitude.		Total duration.
		P_1	P_5	P_1	P_5	
			1901.			
151	June 25	9h 1.8m		3.8mm		7m
152	,, 25	9 59.6		0.6		4.3
153	,, 26	19 20.9		0.8		3.4
154	,, 27	0 58.3		0.7		5.2
155	,, 27	6 27.5		0.5		3.2
156	,, 27	6 41.5		0.5		2.8
157	,, 27	12 23.0		0.9		4.5
158	,, 27	13 32.2		0.7		3.6
159	,, 28	17 40.5		0.5		10
160	,, 28	18 44.0		0.4		3
161	,, 29	15 7.5		0.8		6.5
162	,, 30	0 59.2		1.4		12
163	July 4	15 50.6		0.9		5
164	,, 6	0 44.6		0.5		3
165	,, 6	1 52.9		0.4		3
166	,, 6	2 7.4		0.4		2
167	,, 6	2 54.4		0.3		2.2
168	,, 7	6 10.9		0.6		3
169	,, 7	6 16.7		0.6		3.2
170	,, 10	22 11.4		0.8		3.5
171	,, 10	22 21.2		0.6		3
172	,, 11	10 34.5	10 35.0	Slight.	2.0	8.5
173	,, 14	17 27.2		0.5		2.4
174	,, 14	18 27.3		1.0		4
175	,, 14	18 32.6		0.6		2.5
176	,, 14	19 24.5		0.3		2.4
177	,, 14	20 19.4	20 19.8	—	0.6	3
178	,, 14	22 10.0		4.7		6
179	,, 14	22 33.9		0.4		2
180	,, 14	22 50.0		0.6		3.5

No.	Date.	Time of occurrence.		Amplitude.		Total duration.
		P_1	P_3	P_1	P_3	
		1901.				
181	July 19	14h 27.7m		1.0mm		4m
182	,, 21	9 42.8		2.6		7
183	,, 21	16 22.8		0.4		3.5
184	,, 22	6 57.2		0.6		4
185*	,, 22	7 26.2	7 26.7	—	7.2	10
186	,, 23	7 33.3		0.5		3.5
187	Aug. 9	9 —	—	—	—	Aomori earthquake.
188	,, 9	18 —	—	—	—	Do.
189	,, 10	10 50.9	11 1.1	Very slight.	0.8	53
190	,, 11	11 28.4	11 29.4	Slight.	0.4	13
191	,, 11	14 35.2	14 48.2	Very slight.	0.4	1 30
192	,, 12	12 18.5	12 22.0	Slight.	0.9	35
193	Sept. 24	8 6 2	8 14.1	Very slight.	0.9	45
194	Oct. 1	6 11.7		0.4		2.3
195	,, 4	2 56.1		0.6		2.5
196	,, 5	5 20.1		0.4		3
197	,, 6	0 18.9	0 19.6	Slight.	4.3	4.3
198	,, 6	8 25.0		0.4		2
199	,, 10	10 29.9	10 31.6	0.1	0.6	32
200	,, 19	10 6.0	10 18.0	0.1	1.1	1 10
201	Nov. 4	7 57.6	7 58.4	Slight.	5.5	18
202	,, 6	3 38.2	3 38.5	Do.	0.6	5.5
203	,, 8	6 5.6	6 6.7	Do.	0.8	22
204	,, 27	2 11.4	2 12.4	Do.	1.3	9
205	,, 28	1 25.0	1 25.6	Do.	2.4	12
206	Dec. 5	3 44.4	3 45.7	Do.	0.6	12
207	,, 13	6 19.9		0.4		4
208	,, 13	7 23.0		0.3		3
209	,, 14	23 2.6	23 12.7	0.5	6.0	1 40
210	,, 16	1 22.8	1 23.1	—	0.7	Obscured by a.c.

* Probably not earthquake.

No.	Date.	Time of occurrence.		Amplitude.		Total duration.
		P_1	P_5	P_1	P_5	
1901.						
211	Dec. 16	Obscured by a.c.	13h 26.0m	— mm	7.5mm	—m
212	„ 16	Do.	16 31.0	—	7.0	—
213	„ 18	6 57.6		0.3		3
214	„ 18	7 30.8		0.6		3.5
1902.						
215	Jan. 21	8 20.4		0.5		3 5
216	„ 21	12 53.6	12 54 4	Slight.	0.4	4
217	„ 29	14 26.8	14 27.6	Do.	2.4	7.5
217′	„ 30	14 0	—	—	—	—
217″	„ 31	1 42.0	—	—	—	—
218	„ 31	9 10.0		0.6		3.5
219	„ 31	12 20.7		1.5		2.0
220	Feb. 3	1 45.6		1.5		3.0
221	„ 20	1 49.7	1 50.2	0.2	6.0	17
222	„ 20	15 40.2	15 41 2	0.1	0.7	25
223	„ 21	2 54.5		0.7		4
224	„ 22	4 13.9		0.7		5
225	„ 24	2 13.3		0.5		3.5
226	„ 25	6 49.2		0.5		6
227	March 1	0 15.9	0 21.8	Very slight.	0.6	>135
228	„ 17	1 59.4	1 59.9	Do.	1.2	17
229	„ 17	4 43.9		0.6		4
230	„ 18	1 12.2		0.5		3
231	„ 18	4 37.2		0.6		3.5
232	„ 18	5 58.9		0.8		6
233	„ 18	23 52.1		0.4		3
234	„ 19	4 28.8		0.5		4
235	„ 19	23 44.7		0.6		4
236	„ 23	0 37.8	0 38.2	Slight.	1.5	7
237	„ 25	5 35.3	5 35.6	0.3	4.2	10
238	April 11	23 55.1	24 2.7	Slight.	0.6	27
239	„ 19	2 38.5	3 19.9	0.1	0.9	2 50
240	„ 19	23 18.7	23 19.0	Slight.	2.2	7

No.	Date.	Time of occurrence.		Amplitude.		Total duration.
		P_1	P_5	P_1	P_5	
		1902.				
241	May 2	6h 19.5m	6h 20.0m	Slight.	0.8mm	5.5m
242	„ 2	11 32.0	11 35.2	0.3mm	18.0	1h 50
243	„ 8	2 20.9	2 25.0	0.1	5.0	1 10
244	„ 13	22 39.5		0.9		4
245	„ 28	9 6.7	9 9.4	Slight.	0.7	23
246	June 11	6 15.3	6 22.2	0.1	2.5	1 20
246′	„ 13	0 22.4	0 24.8	Slight.	0.6	15
247	„ 14	8 38.1		0.8		3
248	„ 16	10 12.5		1.7		5
249	„ 20	8 49.2	8 49.6	Slight.	4.0	8
250	„ 22	22 52.9		>13		13
251	„ 23	7 42.6	7 43.2	Slight.	0.5	8
252	„ 26	5 25.5		1.0		3
253	„ 26	7 44.2		0.3		3.5
254	„ 27	13 42.5		3.5		6.5
255	„ 28	7 27.2		1.1		4
256	July 1	8 18.5	8 20.7	Slight.	1.0	20
257	„ 3	15 24.3		0.6		5
258	„ 7	22 2.8		0.6		4
259	„ 8	14 9.1		0.4		8
260	„ 9	7 19.0		0.4		3
261	„ 10	11 0.1	11 1.7	Slight.	0.6	7
262	„ 11	5 21.1		0.3		0.5
263	„ 16	7 35.7		0.6		4
264	„ 18	0 13.7		0.4		2.5
265	„ 20	1 30.6		0.4		4
266	„ 25	22 50.8		0.7		5
267	„ 30	7 18.5		0.5		3
268	Aug. 1	10 19.0		0.7		3.5
268′	„ 2	14 45.0	14 49.5	0.8	2.6	40
269	„ 7	3 35.9		0.8		5
270	„ 7	10 0.5	?	0.1	?	35

No.	Date.	Time of occurrence.		Amplitude.		Total duration.
		P_1	P_5	P_1	P_5	
			1902.			
271	Aug. 22	3h 9.0m	3h 31.5m	Slight.	15.0mm	3h 0m
272	Sept. 21	8	34.6		0.9	3.5
273	„ 21	15	8.7		0.3	2.5
274	„ 21	20	43.0		0.3	5
275	„ 22	1 51.3	2 0.8	1.5	>15.0	2 20
276	„ 23	20 38.6	21 14.4	0.3	0.7	1 20
277	„ 24	9	47.6		0.7	2.5
278	Oct. 10	1 50.4	1 50.8	—	0.3	3
279	„ 10	2	9.8		—	20
280	„ 12	1	23.4		0.8	1
281	„ 13	4	18.8		0.5	12
282	„ 15	16	56.3		1.0	1.5
283	„ 25	0	34.1		0.4	1.5
284	Nov. 2	11	19.7		0.6	2.5
285	„ 7	6	58.7		0.5	1.5
286	„ 15	—	9 37.0	—	1.1	3.0
287	„ 19	23	33.0		1.0	4
288	„ 20	20 36.8	21 3.8	Veryslight.	0.7	1 10
289	„ 21	—	7 13.9	—	1.2	1 20
290	„ 24	5	8.4		0.5	3
291	„ 29	1	28.3		0.4	3
292	Dec. 6	4	19.2		0.3	2
293	„ 6	7	9.9		0.3	2
294	„ 10	5	40.1		0.3	8
295	„ 13	—	17 27.9	—	0.5	40
296	„ 16	5 22.9	5 42.5	Veryslight.	0.4	1 0
297	„ 19	0	35.3		0.5	3
298	„ 28	1 50.2	2 6.5	0.1	1.7	30

III. Description of more important seismograms.

In the following pages, I give a description of more important seismograms. I have distinguished, when possible, the different phases and estimated their transit velocities.

The earthquakes, which originated in or near Japan, having generally been observed with ordinary Gray-Milne type seismograph at some of the different Meteorological Stations distributed in whole Japan, the time of commencement and the position of their epicentre can be determined with a tolerable accuracy. As regards the earthquakes which occurred in other parts of the world, we have only a few cases in which both data were definitely known, while in many cases these were utterly unknown. In the latter cases, I have taken the observations at different Milne H.P. Stations into account, and, adopting the method of time of arrival or that of duration of the preliminary tremor, obtained the approximate position of the origin.

The position of epicentre and time of arrival at the different Milne H.P. Stations having been given, I have drawn a curve (practically a straight line) representing the relation between arcual epicentral distances and times of arrival, and determined the transit velocity of the corresponding phase and the time of occurrence at the origin. In the course of such graphic study, I have found that the transit velocity for the initial phase observed at the different stations was included within the limits 10–14 km. per sec. for certain earthquakes as eqke. No. 106, or 6-8 km. per sec. for other cases as eqke. No. 289. My view with respect to the observations in the two cases is that the former related to the initial wave of the 1st preliminary tremor, while the latter related to that of the 2nd preliminary tremor. It must be added that there were also the cases as eqke. Nos.7-8, in which the times of commencement at some stations related to one of these phases and at other to the other phase, so that in connecting successively the plotted points which belong to the different categories we get, speaking roughly, two quite distinct straight lines.

When the time curve is regular I have next in each case estimated the transit velocities of the different phases from Hongo observation by dividing the arcual epicentral distance with the time intervals taken in transit. If the curve is not fair, however, I have assumed the transit velocity of P_5 and estimated the other velocities in terms of the duration between the time of arrival of P_5 and the other phases, and the epicentral distance from Tokyo. Thus if d represent the epicentral distance and t the time interval between the arrivals of P_5 and any other phase whose transit velocity is represented by V, we have

$$\frac{1}{V_5} - \frac{1}{V} = -\frac{t}{d}.$$

In using this formula, the value of V_5 was assumed to be 3·3 km. per sec., while that of epicentral distance was, when epicentre could not be definitely determined, estimated according to the formula

$$y = 7{\cdot}5\, x,$$

in which y is the distance (in km.), and x is the duration of preliminary tremor (in sec.).[1]

In typical seismogram, such as that of the Mexico earthquake of Jan. 20th of 1900 (Fig. 5), I have distinguished the 1st and 2nd preliminary tremors, the 1st and 3rd phases of the principal portion and the three succeeding phases, whilst the 2nd phase of the principal portion has usually been ill-defined and could not be distinguished.

That the initial waves of the preliminary tremor and the quick period phase of the principal portion are denoted by P_1 and P_5 has already been said. Let us similarly represent the initial phases of the 2nd preliminary tremor and principal portion by P_2 and P_3, which correspond roughly to the *2nd phase of preliminary tremor* and the beginning of *large waves*, so far as Prof. Milne's notation is concerned. In the seismogram of a distant large earthquake, three other distinct phases being commonly observable at certain regular intervals after P_5, I

1. See Dr. Omori's paper:—*Horizontal pendulum observations of earthquake at Hitotsubashi.* The *Publications*, No. 14, § 47.

have taken them into consideration and termed them P_6, P_7, and P_8 respectively. Calculating the transit velocities of these 7 successive phases by assuming their paths to be parallel to the earth's surface, let us denote the values thus obtained by V_1, V_2,....., and V_8 respectively. P_5, whose transit velocity comes out in many cases to be 3·3 km. per sec., is, according to Prof. Omori the longitudinal wave, while P_8, whose transit velocity is about two-thirds of the former, is the transverse one.

In a few distant large earthquakes, I have distinguished certain phases of the principal portion, which are believed to have been the waves transmitted along the major arc of great circle. In the photograms, they are generally isolated from the end portion of the earthquake motion propagated directly along the minor arc, appearing as if they were waves of longer period than the end portion. I denote them and their transit velocities with the same but dashed notations of the corresponding ones relating to the minor arc.

Epicentral angular distance δ from a seismic station has been calculated according to the forumla

$$\cos\delta = \sin\varphi \sin\varphi' + \cos\varphi \cos\varphi' \cos(\lambda - \lambda'),$$

where φ and φ' denote the latitudes of the epicentre and the seismic station, and λ and λ' their longitudes respectively. If accuracy is not required, the value has directly been measured on one of Johnston's 12 inch terrestrial globes. It was found that an error which is committed by adopting the latter method was not greater than 2 % of the calculated value.

Abbreviations for pulsatory oscillations and air current are the same as in the preceding list; the following new abbreviations are added :—

p.t. ... ... preliminary tremor,
p.p. ... ... principal portion,
e.p. ... ... end portion,
d m. ... ... diagramatic maxima,
amp ... ... amplitude,

strong (r.w.) ... ... strong (rather weak),
weak (r.s.) ... ... weak (rather slight),
v.m. ... ... vertical movement,
a.s. ... ... after-shocks,
e.s. ... ... earthquake sound.

Transit velocity, unless otherwise stated, is given in km. per sec.

Eqke No. 1. July 24th 1899 ; 1h 23·3m.

Duration of the p.t. = 3·0m.
Total duration = 1h 29m.
P_1, which arrived at 1h 23·3m, was slight.
P_3, which arrived at 1h 26·3m, had an amp. of 0·3m.

In the seismogram, 4 distinct d.m. were to be recognized, the most conspicuous of which arrived at 1h 48·2m and had an amp. of 1·2mm.

About this earthquake, I could find no other information than the observation with Omori's H.P. in the "Earthquake-proof House" at the University ground. From the duration of the p.t., which was also 3·0 m in the record of Omori's H.P., the epicentral distance may be estimated at about 12°, so that the origin was probably situated far off the Pacific coast of Main Island, probably in the *Bonin curve*.

Eqke No. 3. Sept. 4th 1899 ; 0h 31·2m.

This was a large Alasca earthquake. According to Prof. Omori, the origin was situated off Cape St. Elias at a point long. = 140° W, lat. = 60° N. The times of commencement at, and epicentral distances from, the different Milne H.P. Stations were as follows :—

Shide	0h 34·9m,	64.°	Cape of Good Hope ...	0h 46·2m,	152.°
Kew	0 33·6,	64.	Toronto	0 30·2,	40.
San Fernando ...	0 33·6,	75.	Victoria	0 26·2,	15.

Assuming all these observations to have related to P_1, we get, as a result of graphic deduction (Fig. 1,a), 0h 24·2m as the time of occur-

rence at the origin and 12·9 km. per sec. as the transit velocity of P_1.

Hongo register :—

At the time of this earthquake our instrument was unfortunately in a bad state such that the damping coefficient of the vibrations of the pendulum boom was 1·2 per min., while its value at ordinary state is about 0·53 per min.

Duration of the 1st p.t. = 7·0m.
Duration of the 2nd p.t. = 10·0m.
Total duration = 1h 20m.
P_1, which arrived at 0h 31·2m, had an amp. of 0·1mm.
P_2 ,, ,, 0h 38·2m, ,, 0·4mm.
P_3, ,, ,, 0h 48·2m, ,, 1·2mm.
P_5, ,, ,, 0h 57·3m, ,, 0·5mm.
Other phases were not clearly marked.

Taking the time of commencement at the origin and the epicentral distance from Tokyo (6100 km.) into account, we get from the Hongo observation

$$V_1=14{\cdot}5,\ V_2=7{\cdot}3,\ V_3=4{\cdot}2,\ \text{and}\ V_5=3{\cdot}1.$$

Eqke No. 4. Sept. 9th 1899 ; 2h 2·8m.

This earthquake originated probably off the coast of N.E. Japan. Observations at the different Meteorological Stations were as follows :—

Akita	1h 55m 32s.	Slight.[1]
Mito	2 3 7.	,,

Hongo register :—

Duration of the p.t. = 1·2m.
Total duration = 49m.
P_1, which arrived at 2h 2·8m, had an amp. of 0·5mm.
P_5, ,, ,, 2h 4·0m, ,, 3·6mm.

The beginning of the p.p. was sudden ; a d.m. of an amp. of 3·6mm. was registered at 6·6m. later.

1. Intensity is expressed in the scale adopted by the *Central Meteorological Observatory*.

Eqke No. 7. Sept. 20th 1899 ; 2h 24·5m.

This was a great Smyrna earthquake, which ruined many towns and villages around Aidin in Asia Minor. The times of commencement at, and epicentral distances from, the different Milne H.P. Stations were as follows :—

Shide	...	2h	16·4m,	24.°	Batavia	2h	30·0m ?), 70.°
Kew	...	2	16·7,	24.	Cape of Good Hope	32	4 , 73.
Bombay	...	2	23·8,	44.	Toronto	2	32·9 , 78.
San Fernando		2	17·4,	25.	Victoria	2	35·5 , 90.

In our seismogram, the commencement of the 1st p.t. is uncertain while that of the 2nd p.t. is clearly marked. From this fact, as well as, from the graphic study of the relation between the times taken in transit and the epicentral distances of the above stations, I have assumed the observations at the nearer stations such as Shide, Kew, and San Fernando to have related to P_1, and those at the other stations to P_2. Combining the 1st set of observations with that given by Omori's H.P., we get 2h 13·3m as the time of occurrence at the origin and 13·5 km. per sec. as the transit velocity of P_1. The 2nd set of observations gives 2h 12·5m as the time of occurrence at the origin, and 6·9 km. per sec. as the transit velocity of P_2. (See Fig. 1,a).

Hongo register :—

Duration of the 1st p.t. = 10·8m.

Duration of the 2nd p.t. = 12·7m.

Total duration = 2 h 50m.

The 1st P.T. began very gradually, and was only clearly perceptible at 2h 28·0m. The time of commencement given by Omori's instrument was 2h 24·5m.

P_2, which arrived at 2h 35·3m, had an amp. of 0·2 mm.

P_3, ,, 2h 48 0m, ,, 0·5 mm.

P_5, ,, 3h 0·0m, ,, 0·7 mm.

P_6 was masked by a d.m., which arrived at 3h 7·1m and had an amp. of 4·0mm.

P_7, which arrived at 3h 16·3 m, had an amp. of 0·2mm.

P_8, which arrived at 3h 22·5 m, had an amp. of 0·2mm.

Quite isolated from the e.p., the two waves P_5' and P_6' were registered at 4h 51m and 5h 9m respectively. The former, which had an amp. of 0·05mm. might possibly correspond to P_5 transmitted along the major arc of the great circle, and the latter, which had an amp. of 0·2mm., to P_6.

According to Prof. Omori, the epicentral distance from Tokyo being 9200km., we get, on assuming 3h 12·9m as the time of commencement at the origin,

$V_1=13·3$, $V_2=6·9$, $V_3=4·4$, $V_5=3·26$, $V_6=2·83$,

$V_7=2·46$, $V_8=2·20$, $V_5'=3·25$, and $V_6'=2·92$.

Eqke. No 8. Sept. 23rd. 1899; 11h 20·9m.

This earthquake was probably one of the after-shocks of the great Alasca earthquake which had occurred in the earlier part of this month. The times of commencement at, and the epicentral distances from, the different Milne H.P. Stations were as follows:—

Shide	11h 23·3m,	63.°	Mauritius	11h 44·4m,	137.°
Kew	11 23·3,	63.	Cape of Good Hope	11 48·0,	152.
Bombay	11 28·5,	95.	Toronto	11 19·3,	43.
San Fernando	11 15·2,	67.	Victoria	11 8·4,	14.

I have assumed, taking the graphic representation between the times of arrival and epicentral distances of the different stations into account (Fig. 1,a), the observations at Victoria and San Fernando to have related to P_1, and the others to P_2. Thus, we get 0h 6·3 m as the time of occurrence at the origin, and 13·8 and 6·7km. per sec. as the transit velocities of P_1 and P_2 respectively.

Hongo register:—

The essential part of the whole earthquake motion was obscured by p.o.

P_2, which arrived at 11h 20·9m, had an amp. of 0·2mm.

P_3 and P_5 were masked by p.o.

P_6, which arrived at 11h 42·9m, had an amp. of 1·9mm.

For the transit velocities, we get

$$V_2=7\cdot0, \text{ and } V_6=2\cdot78.$$

Eqke. No. 9. Sept. 29th 1899; 17h 11·6m.

This was a great earthquake which caused much damage along the southern coast of Ceram Island and in Moluccas. The times of commencement at, and the epicentral distances from, the different Milne H.P. stations were as follows:—

Shide	17h 22·2m,	117.°	Batavia	17h 7·3m,	21.°
Kew	17 23·2,	117.	Cape of Good Hope	17 28·5,	104.
Bombay	17 13·6,	59.	Victoria	17 18·5,	104.
San Fernando	17 26·0,	127.			

Assuming the observations at Cape of Good Hope to have related to P_2, we get, as a result of graphic study (Fig. 1,a), 17h 4·3m as the time of occurrence at the origin, and 12·0km. per sec. as the transit velocity of P_1.

Hongo register:—

Duration of the 1st p.t. = 5·0m.

Duration of the 2nd p.t. = 5·0m.

Total duration = 2h 30m.

P_1, which arrived at 17h 11·6m, had an amp. of 0·1mm.

P_2, ,, 17h 16·6m, ,, 1·0mm.

P_3, ,, 17h 21·6m, ,, 2·2mm.

This phase was recorded by Omori's instrument as one of an amp. of 16·5 and a period of 57 sec.

P_5, which arrived at 17h 28·6m, had an amp. of 4·2mm.

P_6, ,, 17h 33·6m, ,, 0·8mm.

P_7, ,, 17h 38·6m, ,, 1·2mm.

P_8, ,, 17h 42.7m, ,, 0·6mm.

D. m. which were registered are 5 in number, of which those at 17h 39m and 17h 45m were large and had each an amp. of 2·9mm.

The epicentral distance from Tokyo being 4800km., we get from the above data

$$V_1=11{\cdot}0,\ V_2=6{\cdot}3,\ V_3=4{\cdot}6,\ V_5=3{\cdot}28,$$
$$V_6=2{\cdot}73,\ V_7=2{\cdot}33,\text{ and }V_8=2{\cdot}08.$$

Eqke. No. 10. Oct. 4th 1899; 9h 9·0m.

Hongo register:—

Duration of the p.t. = 2·0

Total duration = 1h 10m.

P_1, which arrived at 9h 9 0m, had an amp. of 0·1mm.

P_2 was not distinctly marked.

P_3, which arrived at 9h 11·0m, had an amp. of 0·9mm. It was soon followed by a d.m. of an amp. of 1·9mm.

P_5, which arrived at 9h 12·8m, had an amp. of 1·4mm.

P_6, which arrived at 9h 13·9m, had an amp. of 2·3mm.

Taking the duration of p.t. into account, we get 900km. as the epicentral distance from Tokyo. Considering that such a conspicuous earthquake occurred in comparatively near distance and nowhere registered in the inland Meteorological Stations, the position of the origin must be assumed to be in the Bonin curve as in eqke. No. 1.

Assuming the values of V_5 and the epicentral distance, we get

$$V_3=5{\cdot}4,\text{ and }V_6=2{\cdot}67.$$

Eqke. No. 12. Oct. 19th 1899; 9h 29·1m.

The relative times of commencement at the different Milne H.P. Stations having been very similar to those in the Ceram earthquake of Sept. 29th, the origin was probably situated at a point near the Island of Ceram, the only difference being that it was, in the present case, nearer to Tokyo or Victoria and further from Batavia than that of the former earthquake. Further, the durations of the p.t. at Batavia and Tokyo having been 11·2m and 12·2m re-

spectively, we get a position long. = 153°E, lat. = 12°S for the epicentre of the present earthquake. In the following table the epicentral distances refer to this point.

Shide ... ...9h 44·0m, 136.°	Cape of Good Hope ...9h 44·2m, 121.°
Kew ... ...9 41·8, 137.	Toronto ... ...9 42·6, 128.
San Fernando 9 43·4, 142.	Victoria ... ...9 36.4, 94.
Batavia ...9 28·1, ' 45.	Mauritius ... ...9 34 1, 89.

The graphical study (Fig. 1,a) of the above observations gives us 9h 22·0m as the time of commencement at the origin and 12·3km. per sec. as the transit velocity of P_1.

Hongo register :—

Duration of the 1st p.t. = 6 3m.
Duration of the 2nd p.t. = 5·9m.
Total duration = 1h 0m.

P_1, which arrived at 9h 29·1m, had an amp. of 0·2mm.
P_2, ,, 9h 35·4m, ,, 0·3mm.

A d.m. of an amp. of 1·2mm. was registered at 9h 37·8m.

P_3, which arrived at 9h 41·3m, had an amp. of 2·0mm.
P_5, ,, 9h 46·3m, ,, 3·4mm.

This phase was followed by a pair of d.m., which masked the subsequent phases except P_8.

P_8, which arrived at 10h 2·0m, had an amp. of 1·4mm.

The estimated epicentral distance from Tokyo being 49°, the transit velocities of the different phases come out as follows :—

$V_1 = 12·7$, $V_2 = 6·7$, $V_3 = 4·7$, $V_5 = 3·70$, and $V_8 = 2·26$.

Eqke. No. 17. Nov. 11th 1899 ; 22h 41·8m.

Hongo register :—

Duration of the p.t. = 14m.
Total duration = 54m.

This earthquake occurred probably in the Bonin curve.

Eqke. No. 22. Dec. 30th 1899; 10h 14·1m.

Hongo register:—

Duration of the p.t. = 2·4m.

Total duration = 37m.

This earthquake also occurred probably in the Bonin curve.

Eqke. No. 24. Jan. 11th 1900; 9h 14·5m.

According to Prof. Milne, this earthquake originated at a point long. = 175°E, lat. = 5°S, but taking the duration of the p.t. of 7·6m, which was given by Omori's instrument here, into account, it seems more probable that the origin was situated near Guam Island at a point long = 150°E, lat. = 10°N. The times of commencement at, and the epicentral distances from, the different Milne H.P. Stations were as follows:—

Batavia	9h 17·9m,	44.°	Cairo	9	29·1m, 109.°
Cape of Good Hope ...	9 30·5,	134.	Cordova	9	30·5, 149.
Shide	8 25·6(?),	137.	Victoria	9	22·0, 82.
Kew	9 31·6,	137.	Mauritius ...	9	20·9, 96.
San Fernando	8 29·6(?),	153.			

From the graphic study of the relation between the epicentral distances and the times of arrival at the different stations, we get 9h 11·3m as the time of commencement at the origin, and 13·3km. per sec. as the transit velocity of P_1.

Hongo register:—

Duration of the 1st p.t. = 4·6m. This value is taken from Prof. Omori's observation, as the initial part of this stage was not clearly marked in the seismogram given by our instrument.

Duration of the 2nd p.t. = 3·0m.

Total duration = 1h 30m.

P_2, which arrived at 9h 19·1m, had an amp. of 0·15m.

P_3, ,, 9h 22·1m, was definitely marked and had an amp. of 0·8mm.

P_5, which arrived at 9h 25·8m, was also definitely marked, and had an amp. of 3·2mm.

P_6, which arrived at 9h 28·1m, had an amp. of 4·0mm. It was followed by a d.m. of an amp. of 5·0mm.

P_7, which arrived at 9h 31·5m, followed closely the d.m. above mentioned and had an amp. of 2·5mm.

P_8 was not clearly marked.

As the position of epicentre is not definitely known, let us assume the value of V_5 and estimate the transit velocities of other phases, then we get

$V_3=4·4$, $V_6=3·87$, and $V_7=2·40$.

Eqke. No. 28. Jan. 18th 1900; 7h 46·7m.

This earthquake originated off the southern coast of Hokkaido, at a distance of about 800 km. from Tokyo. Observations at the different Meteorological Stations were as follows:—

Tokachi	7h 45·2m.	Weak.	Gentle.
Nemuro	7 41·2.	Slight.	Duration long.
Fukushima	7 44·3.	,,	
Ishinomaki	7 44·5.	,,	Gentle.
Tokyo	7 46·0.	,,	
Miyako	7 48·7.	,,	

This earthquake was also registered at Victoria, where the earth's movement began at 8h 2·8m and lasted about 30m. The first phase which was observed at that station was probably P_2, for we get as its transit velocity 6·3 km. per sec.

Hongo register:—

Duration of the p.t. = 1·5m.

Total duration = 25m.

P_5, which arrived at 7h 49·0m, had an amp. of 0·35mm.

Eqke. No. 29. Jan. 20th 1900; 6h 47·2m.

This was a Mexico earthquake, which damaged certain buildings

in Jalisco. "An account of the earthquake" written by the vice-director of the Central Meteorologico-magnetic Observatory of Mexico is very important in determining the position of the epicentre and the time of commencement at the origin. The most disturbed area was, according to him, in a district around Mt. Colima, but Guadalajara having been one of the most severely disturbed towns, it may be inferred that the seismic focus was situated near that town probably at a point long.$=104°$ W, lat.$=20°$ N. As regards the times of commencement at the different localities, the most accurate one is probably that which is due to the instrumental observation at the Observatory of Mexico. The p.p., which arrived there at 23h 59m (or 6h 35·5m in G.M.T.) and had an amp. of 33cm. (?), might possibly have been the phase P_5, so that, in subtracting from this a time interval which was taken by P_5 in being propagated through the epicentral distance of 500 km., the time of commencement at the epicentre comes out to have been 6h 33·0m.

The times of commencement at, and the epicentral distances from, the different Milne H.P. Stations were as follows:—

Batavia	6h 53·7m, 143.°	Cordova	6h 43·1m, 64.°
Cape of Good Hope ..	7 3·2, 131.	Toronto	6 40·3, 31.
Kew	6 46·2, 82.	Victoria	6 39·8, 33.
San Fernando	6 45·6, 84.		

The observation at Cape of Good Hope related probably to P_2, while the others related to P_1. In so assuming, we get 6h 35·5m as the time of commencement at the origin and 14·5 km. per sec. as the transit velocity of P_1.

Hongo register:—

Duration of the 1st p.t.$=16·6$m.

Duration of ths 2nd p.t.$=13·9$m.

Total duration $=2$h 30m.

P_1, which arrived at 6h 47·2m, was very slight.

P_2, „ 7h 3·8m, had an amp. of 0·2mm.

P_3, which arrived at 7h 17·7m, had an amp. of 0·2mm.
P_5, ,, 7h 34·6m, ,, 1·0mm.
P_6, ,, 7h 45·5m, ,, 1·4mm.

This phase was followed by 4 successive d.m., each of which had an amp. of 1·6mm.

P_7, which arrived at 7h 52·4m, had an amp. of 0·5mm.
P_8, ,, 8h 2·4m, ,, 1·0mm.

P'_5, which corresponds to the 5th phase propagated along the major arc of the great circle, was observed at 9h 6·6m, and had an amp. of 0·14mm. The waves following it closely might possibly be ones which were transmitted along the same path.

As regards the transit velocities of the different phases, we get the following values :—

$V_1 = 13·2$, $V_2 = 6·1$, $V_3 = 4·2$, $V_5 = 3·04$,
$V_6 = 2·60$, $V_7 = 2·37$, $V_8 = 2·12$, and $V'_5 = 3·22$.

Eqke. No. 33. Feb. 2nd 1900 ; 8h 5·5m.

This earthquake originated in the Eastern Kūshū, off the coast of Hūga. Observations at the different Meteorological Stations were as follows :—

Miyazaki	8h 1·3m.	Weak.	Sharp.
Kagoshima	8 2·2.	Slight.	Gentle.
Fukuoka	8 3·1.	,,	Duration long.
Saga	8 4·1.	,,	,,
Kumamoto	8 4·5.	,,	,,

Hongo register :—
Duration of the p.t. = 1·5 m.
Total duration = 10 m.
P_1, which arrived at 8h 5·5m, had an amp. of 0·1mm.
P_5, ,, 8h 8·0m, ,, 0·5mm.

Eqke. No. 34. Feb. 3rd 1900 ; 4h 24·7m.

Observations at the different Milne H.P. Stations were as follows :—

Kew	5h 17·0m.	Victoria	5h 18·9m.
Batavia	4 15·7.	Mauritius	4 26·9.
Toronto	5 30·8.		

The origin was probably situated near Batavia. Assuming the observations at Kew, Toronto, and Victoria to have related to P_5, we get 3·45 km. per sec. as its transit velocity.

Hongo register :–

Duration of the p.t. = 13·5m.

Total duration = 45m.

P_1, which arrived at 4h 24·7m, had an amp. of 0·1mm.

P_3, ,, 4h 38·2m, ,, 0·3mm.

At 4h 41·0m, a d.m. of an amp. of 0·85mm. was registered.

Eqke. No. 36. Feb. 13th 1900; 4h 27·9m.

This earthquake originated off the coast of N.E. Japan. Observations at the different Meteorological Stations were as follows :—

Ishinomaki	4h 25·8m.	Slight.	Accompanied by e.s.
Fukushima	4 26·6.	,,	
Nemuro	4 27·7.	,,	Gentle.
Tokyo	4 28·3.	,,	
Utsunomiya	4 28·3.	,,	
Mito	4 28·3.	,,	Windows rattled.
Akita	4 29·5.	,,	
Kumagai	4 29·8.	,,	
Kōfu	4 29·9.	,,	Gentle.
Miyako	4 31·6.	,,	Accompanied by v.m.
Kushiro	4 33·1.	,,	
Aomori	4 38·4.	,,	Gentle.

Hongo register :—

Duration of the 1st p.t. = 1·2m.

Duration of the 2nd p.t. = 0·8m.

Total duration =22m.

P_1, which arrived at 4h 27·9m, had an amp. of 0·1mm.
P_2, ,, 4h 29·1m, ,, 0·3mm.
P_3, ,, 4h 29 9m, ,, 0·8mm.
P_5, ,, 4h 30·8m, ,, 2·3mm.

Other phases were not distinctly marked.

Eqke. No. 43. March 9th 1900; 2h 36·0m.

The origin of this earthquake was probably near to that of the Ceram earthquake of 1899, the relative times of arrival of the initial phase at the different Milne H.P. Stations and of the various phases in the Hongo register having been similar in the two cases. The epicentral distances from the different stations and the times of occurrence at the latter were as follows:—

Shide	2h 54·0m,	118.°	Cordova	3h 25·9m,	143.°
Kew	2	48·0,	118.	Toronto	2	47·0,	135.
San Fernando ...	3	38·4,	130.	Victoria	2	42·1,	108.
Batavia	2	31·5,	20.				

Studying the above observations graphically (Fig. 1,a), we get 2h 29·5m as the time of occurrence at the origin and 12·9km. per sec. as the transit velocity of P_1.

Hongo register:—

Duration of the 1st p.t.=5·3m.

Duration of the 2nd p.t.=7·3m.

Total duration was greater than 1h 10m. (The e.p. was not recorded as the clock stopped at 3h 45m.)

P_1, which arrived at 2h 36·0m, had an amp. of 0·1mm.
P_2, ,, 2h 41·3m, ,, 0·3mm.
P_3, ,, 2h 48·6m, ,, 0·6mm.

At 2h 51·5m, a d.m. of an amp. of 1mm. was registered.

P_5, which arrived at 2h 54·3m, had an amp. of 1·1mm.

P_6,	,,	2h 58·2m,	,,	0·8mm.
P_7,	,,	3h 2·0m,	,,	0·4mm.
P_8,	,,	3h 7·2m,	,,	0·4mm.

As the position of the seismic focus was not definitely known, let us calculate the transit velocities of the different phases, assuming the value of V_5 and the epicentral distance estimated from the duration of the p.t. Thus we get

$$V_3=4·3,\ V_6=2·84,\ V_7=2·51,\ \text{and}\ V_8=2·15.$$

Eqke. No. 44. March 12th 1900; 1h 34·6m.

This earthquake originated off the coast of N.E. Japan at 1h 34·0m. Observations at the different Meteorological Stations were as follows:—

Ishinomaki	...1h 33·9m.	Strong.	Duration long.
Akita ...	...1 31·5.	Strong (r. w.)	Accompanied by v.m. houses shaken.
Miyako ...	.. 1 34·5.	,,	Accompanied by v.m.
Kanayama	.. 1 35·0.	,,	
Yamagata	...1 35·0.	Weak.	Houses shaken.
Kumagai	..1 35·1.	,,	Gentle.
Aomori ...	...1 35·1.	,,	,,
Fukushima	...1 35·3.	,,	Sharp, houses shaken, accompanied by e.s.
Kōfu ...	...1 35·5.	,,	Accompanied by v.m., houses shaken.
Yokohama	...1 35·5.	,,	
Tokyo ...	...1 35·6.	,,	Gentle.
Mito ...	...1 35·9.	,,	Accompanied by v.m., houses shaken.
Nagano ...	...1 35·5.	Slight.	Duration long.
Utsunomiya	...1 33·8.	,,	Sharp.
Chōshi ...	...1 35·1.	,,	Gentle.

Niigata ...	...1h 35·4m.	Slight.	Gentle,
Numazu ...	...1 36·1.	,,	,,
Iida ...	...1 36·5.	,,	Duration long.
Maebashi	...1 36·8.	,,	
Nagoya ...	...1 37·1.	,,	Gentle.

The times of commencement at, and the epicentral distances from, the different Milne H.P. Stations were as follows :—

Shide ...	...1h 58·1m, 88.°	Toronto	...1h 59·7m, 92.°
Kew ...	...1 56·8, 87.		

These observations related to P_2, so that we get 6·9km. per sec. as its transit velocity. (See Fig. 1,a.)

Hongo register :—

Duration of the p.t. = 0·8m.

Duration of the p.p. = 19m.

Total duration was longer than 1h. The e.p. was obscured by a.c.

P_1, which arrived at 1h 34·6m, had an amp. of 0·4mm.

P_3, ,, 1h 35·4m, ,, 6·0mm.

Following P_3, 4 distinct large waves were registered within 3m.

Eqke. No. 50. April 14th 1900 ; 22h 49·4m.

The origin was near Tokyo. Observations at the different Meteorological Stations were as follows :—

Mito ...	...22h 51·6m.	Weak.	Sharp.
Akita ...	...22 42·9.	Slight.	
Tokyo ...	...22 50·5.	,,	
Yokohama	..22 50·6.	,,	Duration long.
Yokosuga	...22 50·7.	,,	Accompanied by v.m.
Kōfu ...	...22 50·9.	,,	
Matsumoto	...22 51·2.	,,	
Maebashi	...22 51·2.	,,	

Kumagai ...22h 52·1m. Slight.
Nagano ...22 52·8. „

Hongo register :—
Duration of the p.t. = 0·4m.
Total duration = 13m.
P_1, which arrived at 22h 49·4m, was slight.
P_3, „ 22h 49·8m, had an amp. of 5·4mm.

Eqkc. No. 52. April. 24th 1900; 23h 19·3m.

Prof. Omori observed in this case two earthquakes, one at 23h 18·9m and the other at 18h 23·0m. These earthquakes, which might possibly be a single one, occurred at 21h 16·0m off the southern coast of Formosa at a distance of about 2500 km. from Tokyo. Observations at the different Meteorological Stations were as follows :—

Tainan	23h 16·9m.	Weak.	Gentle.
Taihoku	23 17·4.	Slight.	Duration long.
Oshima	23 16·0.	„	Houses shaken.
Tsu	23 18·5.	„	Duration long.
Oita	23 19·0.	„	
Saseho	23 19·1.	„	
Tokyo	23 19·2.	„	
Akita	23 19·2.	„	Duration long.
Wakayama	23 19·4.	„	
Kofu	23 19·6.	„	Duration long.
Kumagai	23 20·0.	„	
Aomori	23 20·1.	„	Gentle.
Yokohama	23 20·6.	„	„
Osaka	23 20·6.	„	„
Iida	23 20·7.	„	
Mito	23 21·0.	„	
Fukushima	23 21·9.	„	Duration long.
Hikone	23 22·8.	„	

Yokohama	23h 23·1m.	Slight.	Gentle.
Miyako	23 26·6.	,,	
Yagi	23 40·0.	,,	
Nagoya	23 23·6.	,,	Gentle.

The times of commencement at, and the epicentral distances from, the different Milne H.P. Stations were as follows :—

Shide	23h 28·9m, 98.°	Bombay	23h 23·4m(?), 49.°
Kew	23 30·0(?), 97.	Batavia	22(?)17·5, 30.
San Fernando ..	23 34·4, 111.	Toronto	23 34·2, 120.
Cairo	23 29·1, 84.	Mauritius	23 24·9, 71.
Madras	23 21·9, 41.		

Studying graphically (Fig. 1,a), we get 23h 16·0m as the time of commencement at the origin and 12·5 km. per sec. as the transit velocity of P_1.

Hongo register :—

Duration of the p.t. = 4·7m.

Total duration = 2h 0m.

P_1,	which arrived at	23h 19·3m,	had an amp. of	0·2mm.
P_3,	,,	23h 24·0m,	,,	1·6mm.
P_5,	,,	23h 27·7m,	,,	2·7mm.
P_6,	,,	23h 30·0m,	,,	1·2mm.
P_7,	,,	23h 32·4m,	,,	1·1mm.
P_8,	,,	23h 34·8m,	,,	0·7mm.

As the position of the seismic focus was not definitely known, I have assumed the value of V_5, and calculated the transit velocities of the other phases, the epicentral distance taken into account having been estimated from the duration of the p.t. Thus we get

$$V_3 = 4{\cdot}7,\ V_6 = 2{\cdot}78,\ V_7 = 2{\cdot}41, \text{ and } V = 2{\cdot}11.$$

Eqke. No. 52. May 11th 1900 ; 17h 24·2m.

This Japan earthquake was accidentally lost by our instrument,

but the position of its epicentre and the time of occurrence at the origin having been well known, it will be interesting to study how the earthquake was propagated to the other Milne H.P. Stations. Observations at the different Meteorological Stations were as follows:—

Ishinomaki	17h	23·2m.	Strong	Sharp, accompanied by e.s. v.m., and a.s.
Fukushima	17	23·6.	,,	Sharp, accompanied by v.m. and a.s.
Kanayama	17	23·0.	,,	
Kofu	17	20·9.	Strong(r.w.)	Accompanied by v.m., houses shaken.
Akita	17	22·3.	,,	Accompanied by v m., clocks stopped.
Mito	17	23·2.	,,	Sharp, houses shaken, accompanied by v.m.
Kumagai	17	24·0.	,,	Houses shaken, accompained by v.m.
Aomori	17	24·3.	,,	Gentle.
Yokohama	17	24·4.	,,	Accompanied by v.m., clocks stopped.
Yamagata	17	24·5.	,,	Houses shaken.
Niigata	17	25·2.	,,	
Miyako	17	29·7.	,,	Accompanied by v.m.
Nagano	17	23·3.	Weak	Duration long.
Utsunomiya	17	23·7.	,,	Sharp, accompanied by v.m.
Tokyo	17	24·2.	,,	Clocks stopped.
Yokosuga	17	24·9.	,,	Windows rattled.
Tokachi	17	25·0.	,,	Gentle.
Gifu	17	25·1.	,,	Duration long.
Numazu	17	25·2.	,,	Gentle.
Hakodate	17	25·3.	,,	Houses shaken.
Mera	17	25·5.	,,	,,
Hikone	17	59·4.	,,	Gentle.
Maebashi	17	24·3.	Slight.	
Iida	17	24·2.	,,	Duration long.

Fukui	17h 24·5m.	Slight.
Choshi	17 25·0.	,, Gentle.
Nagoya	17 25·2.	,, ,,
Tsu	17 25·5.	,, Duration long.
Nemuro	17 27·0.	,, Sharp.
Yagi	17 30·0.	,, Gentle.
Sapporo .. .	17 35·2.	,, ,,
Matsumoto ..	17 42·6.	,, ,,

From the above observations, it will be seen that the epicentre was situated off the coast of the Provinces of Rikuzen and Iwaki. The epicentral distances from the different Milne H.P. Stations and the times of commencement observed at the latter were as follows:—

Shide	17h 36·6m,	86.°	Cape of Good Hope	17h 36·3m,	135.°
Kew	17 35.3,	84.	Bombay	17 42·3,	62.
San Fernando	17 48·0,	101.	Batavia	18 10·0,	53.
Cairo	17 48·1,	89.	Victoria	17 33·4,	67.

The observations at Shide, Kew, and Victoria related to P_1, and those at San Fernando, Cairo, and Bombay to P_2. From the graphic study (Fig. 1,a), we get

$$V_1 = 12{\cdot}2, \text{ and } V_2 = 6{\cdot}7.$$

Eqke. No. 56. June 2nd 1900; 21h 39·7m.

I could not find any other observation relating to this earthquake except that by Prof. Omori. He observed the duration of the p.t. to have been 15·8m, while my estimation of the same was only 3·2m which agrees with the value given by our Milne H.P. seismogram. Further, the character of the earthquake resembled in every respect to that of eqke. No. 12, so that the present earthquake originated probably in the Bonin curve.

Hongo register:—

Duration of the p.t. = 3·0m.

Total duration = 1h 20m.

P_1, which arrived at 21h 39·7m, had an amp. of 0·2mm.
P_3, ,, 21h 42·7m, ,, 1·5mm.
P_5, ,, 21h 44·8m, ,, 1·2mm.
P_6, ,, 21h 46·3m, ,, 1·9mm.
P_7 was not clearly marked.

P_8, which arrived at 21h 48·4m, had an amp. of 0·8mm. Assuming the values of V_5 and the epicentral distance, we get

$$V_3 = 4{\cdot}7,\ V_6 = 2{\cdot}73, \text{ and } V_8 = 2{\cdot}18.$$

Eqke. No. 66. Aug. 5th 1900; 4h 20·7m.

This earthquake, which occurred at 4h 19·5m, originated, as eqke. No.52′, off the coast of the Provinces of Iwaki and Rikuzen. Observations at the different Meteorological Stations were as follows:—

Ishinomaki	···4h 19·8m.	Strong.	Sharp, houses shaken, accompanied by v.m.
Mito ··· ···	··4 17·4.	Strong(r.w.).	,,
Miyako ···	··4 18·8.	Weak.	Accompanied by v.m.
Choshi ···	··4 19·6.	,,	Duration long.
Akita·· ···	···4 19·9.	,,	Houses shaken, accompanied by v.m.
Kanayama	···4 20·6.	,,	Houses shaken.
Yamakata ···	···4 21·0.	,,	,,
Tokyo ···	···4 21·1.	,,	
Yokohama ··	··4 21·3.	,,	Houses shaken.
Kōfu ·· ··	···4 21·4.	,,	Sharp, houses shaken, accompanied by v.m.
Yokosuga ···	··4 22·1.	,,	Gentle.
Utsunomiya	··4 22·2.	,,	,,
Aomori ···	···4 22·2.	,,	,,
Fukushima	···4 22·7.	,,	Sharp, houses shaken, accompanied by v.m.
Kumagai ··	··4 31·3.	,,	Houses shaken, accompanied by v.m.
Niigata ···	···4 20·4.	Slight.	Gentle.

Maebashi ...	...4h 21·1m.	Slight. Duration long.
Numazu ...	4 21·3.	,,
Fukui ...	4 21·6.	,,
Tsu ...	...4 21·9.	,,
Wajima ...	...4 22·0.	,,
Matsumoto	...4 22·5.	,, Duration long.
Hikone ...	4 22·5.	,, Gentle.
Nagoya ...	...4 22·7.	,, ,,
Iida	...4 24·4.	,,

The times of commencement at, and the epicentral distances from, the different Milne H.P. Stations were as follows :—

Shide ...	...5h 5·5m, 85.°	San Fernando ...	...5h 13·2m, 100.°
Kew	5 3·0, 83.	Cape of Good Hope	5 30·9, 134.
Toronto ...	4 44·0, 81.	Calcutta	...4 37·2, 48.
Victoria ...	...4 40·0, 66.	Batavia	...4 37·2, 55.

Of the above observations, those at Shide, Kew, San Fernando, and Cape of Good Hope related to P_3, and those at the others to P_2. (Victoria Nos. 205–206 related probably to the present earthquake.) Studying graphically (Fig. 1,a), we get

$$V_2 = 6{\cdot}0, \text{ and } V_3 = 3{\cdot}45.$$

Hongo register :—

Duration of the p.t. = 0·8m.

Duration of the p.p. = 25m.

Total duration = 1h 20m.

P_1, which arrived at 4h 20·7m, had an amp. of 0·4mm.

P_3, ,, 4h 21·5m, had an amp. of 14·8mm. For 2·5m after its arrival, the displacement was immeasurably large, then it became gradually small until it was reduced at 4h 46m to an amp. of 1·5mm.

Eqke. No. 69. Sept. 24th 1900; 3h 35·4m.

This earthquake originated off the coast of Mutsu at a distance

of about 600km. from Tokyo. Observations at the different Meteorological Stations were as follows:—

Aomori	3h 33·3m.	Weak.	Windows rattled.
Miyako	3 34·5.	,,	Accompanied by v.m.
Ishinomaki	3 36·6.	,,	
Akita	3 34·8.	Slight.	
Kumagai	3 35·0.	,,	
Mito	3 36·0.	,,	
Choshi	3 36·1.	,,	Sharp.
Maebashi	3 36·4.	,,	
Tokyo	3 36·4.	,,	
Kōfu	3 36·9.	,,	Gentle.
Wajima	3 40·0.	,,	,,
Fukushima	3 41·2.	,,	Houses shaken.
Hakodate	3 43·0.	,,	

Hongo register:—

Duration of the p.t. = 1·4m.

Total duration = 12m.

P_1, which arrived at 3h 35·4m, had an amp. of 0·6mm.

P_3, ,, 3h 36·8m, ,, 1·1mm.

P_5, ,, 3h 37·7m, ,, 1·2mm.

P_6 and P_7 were not distinctly marked.

P_8, which arrived at 3h 39·7m, had an amp. of 1·1m.

From the epicentral distance and the transit velocity of P_5, we get

$$V_3 = 4·7, \text{ and } V_8 = 1·99.$$

Eqke. No. 71. Oct. 7th 1900; 21h 9·2m.

According to Prof. Milne, this earthquake originated near the Philippine Archipelago at a point long. = 140° E, lat. = 4° N. Observations at the different Milne H.P. Stations were as follows:—

Shide	21h 35·3m, 116.°	Cape of Good Hope	21h 29·5m, 120.°

Kew	21h 31·2m, 115.°	Calcutta	21h 12·8m, 51.°
Toronto	21 32·1, 122.	Bombay	21 14·6, 67.
Victoria	21 26·1, 91.	Madras	21 21·2, 60.
San Fernando ...	21 26·9, 129.	Batavia	21 9·7, 34.

The observations at Calcutta, Bombay, and Batavia related to P_1, and those at Madras and Shide to P_2. Studying graphically (Fig. 1,a), we get 21h 4·8m as the time of occurrence at the origin, and 12·7 km. per sec. as the transit velocity of P_1.

Hongo register :—

Duration of the 1st p.t. = 6·0m.

Duration of the 2nd p.t. = 5·0m.

Total duration = 2h 15m.

P_1,	which arrived at	21h 9·2m,	had an amp. of	0·2mm.
P_2,	,,	21h 15·2m,	,,	0·3mm.
P_3,	,,	21h 20·2m,	,,	2·1mm.
P_5,	,,	21h 25·4m,	,,	3·0mm.
P_6,	,,	21h 28·8m,	,,	5·5mm.
P_7,	,,	21h 31·6m,	,,	5·0mm.
P_8,	,,	21h 36·1m,	,,	2·6mm.

As the position of the epicentre was not definitely known, I have estimated the transit velocities of the different phases by assuming the values of V_5 and the epicentral distance (3500 km.). Thus we get

$$V_3 = 4·7,\ V_6 = 2·77,\ V_7 = 2·45, \text{ and } V_8 = 2·04.$$

Eqkc. No. 72′. Oct. 8th 1900 ; 9h 2·3m.

Observations at the different Milne H.P. Stations were as follows :—

Toronto	9h 24·0m.	Madras	9h 16·5m.
Victoria	9 23·1.	Batavia	9 3·7.

During this earthquake, the boom of our instrument received successive jerks so that the character of waves was obscured.

Eqke. No. 73. Oct. 9th 1900; 12h 37·0m.

This earthquake originated probably off the S.W. coast of Alasca near the locality where many large earthquakes had occurred in Sept. of the previous year. The times of commencement at, and the epicentral distances from, the different Milne H.P. Stations were as follows:—

Shide ...	...12h 39·9m, 69.°	Cape of Good Hope	..12h 49m, 153.°
Kew ...	...12 34·7, 68.	Bombay	...12 52·2, 99.
Toronto ...	...12 37·1, 43.	Madras	...12 44·6, 102.
Victoria ...	.. 12 32·1, 16.	Batavia	...12 46·5, 105.
San Fernando	..12 37·8, 80.		

From the graphic study of the relation between the times of commencement and the epicentral distances (Fig. 1,a), it follows that the above observations related to P_1, except those at Kew and Bombay. Thus we get 12h 30m as the time of commencement at the origin, and 13·7 km. per sec. as the transit velocity of P_1.

Hongo register:—

Duration of the 1st p.t.=7·7m.

Duration of the 2nd p.t.=4·0m.

Total duration =3h 20m.

P_1, which arrived at 12h 37·0m, had an amp. of 0·6mm. A d.m. of an amp. of 1·5mm. was registered at 12h 40·0m.

P_2, which arrived at 12h 44·7m, had an amp. of 2·0mm. Another d.m. of an amp. of 4·5mm. was registered at 12h 47m.

P_3, which arrived at 12h 44·3m, had an amp. of 2·5mm.

P_5, ,, 12h 56·0m, ,, 2·2mm.

P_6, ,, 13h 1·2m, ,, 1·7mm.

P_7, ,, 13h 5·4m, ,, 1·3mm.

P_8, ,, 13h 10·9m, ,, 1·8mm,

According to the seismogram given by Omori's instrument, the p.t. consisted principally of the waves whose period was about 15 sec., while the waves in the p.p. had very long period, so that in our

seismogram, the p.t. was well marked, but the p.p. was comparatively small.

From the values of V_5 and the estimated epicentral distance, we get

$$V_3=4\cdot4,\ V_6=2\cdot79,\ V_7=2\cdot48,\ \text{and}\ V_8=2\cdot16.$$

Eqke. No. 77. Oct. 18th 1900; 18h 33·6m.

This earthquake occurred probably at a point not very far from Batavia. Observations at the different Milne H.P. Stations were as follows:—

Victoria	19h 23·0m.	Calcutta	18h 47·5m.
Mauritius	18 48·1.	Batavia	18 27·7.

The 1st observation related probably to P_5, while the last related to P_1.

Hongo register:—

Duration of the 1st p.t. = 9·0m.

Total duration = 1h 0m.

P_1,	,,	18h 33·6m,	was very slight.
P_3,	,,	18h 42·6m,	had an amp. of 0·1mm.
P_5,	,,	18h 47·8m,	,, 0·5mm.
P_6,	,,	18h 50·8m,	,, 0·5mm.

The subsequent phases were not clearly marked.

From the values of V_5 and estimated epicentral distance, we get

$$V_3=4\cdot4,\ \text{and}\ V_6=2\cdot87.$$

Eqke. No. 77′. Oct. 29th 1900.

This was a large Caraccas earthquake. Unfortunately, it was not registered by our instrument, but it is interesting to see how the earthquake waves were propagated to the different Milne H.P. Stations.

Kew	9h 21·5m, 66.°	Cape of Good Hope	9h 25·0m, 83.°
Toronto	9 18·1, 34.	Bombay	9 32·5, 133.
Victoria	9 20·7, 60.	Madras	9 34·0, 142.
San Fernando	9 21·1, 60.	Batavia	9 32·4, 175.

To these observations I add another obtained here by Omori's instrument which recorded the initial phase at 9h 31·9m. Studying graphically (Fig. 1,a), we get 14·5km. per sec. as the transit velocity of P_1.

Eqke. No. 79. Nov. 5th 1900; 7h 41·3m.

This earthquake originated near the Izu Islands, at a distance of about 200km. to the south of Tokyo. A full description of the earthquake phenomena was given by Mr. Fukuchi, *Rigakushi*, who stayed for two months from April 1901 in the disturbed isles of Mikura, Miyake, and Kōzu. The following lines are the sketch of his report.[1]

"The epicentre was in the sea-bottom between the two islets called Zeni and Inanba. Fore-shocks were felt in Miyake since the 4th of November, increasing gradually in number and intensity, until the maximum was attained at 7h 51m of the next day. The principal earthquake, which occurred at the last-mentioned time, gave a slight damage in the three islands, the intensity at Mikura being *violent* according to the scale adopted by the Central Meteorological Observatory, or the 8th of Rossi-Forel's scale.

"No house was damaged, but many stone walls and grave stones fell, cliffs were rent, and rocks and stones on the summit of lofty ridges fell down; one of the inhabitants in Mikura having been killed by one of the falling stones.

"After-shocks were felt for several months. At Mikura, a daily frequency was more than 40 for a few days immediately after the catastrophe, but it was reduced to 6 or 7 after a week, and to 2 or 3 after a month."

The epicentre having been under the sea-bottom at a distance of about one hundred km. from the Main Island, the earthquake was felt *strongly* only at the nearer stations, yet it was registered by ordinary seismograph of Gray-Milne type even at a radial distance of 800km. Observations at the different Meteorological Stations were as follows:—

1. See Reports (Japanese) of the Imp. Earthq. Inv. Comm., No. 38.

Nov. 5th.

Mera	5h	8·8m.	Weak.	Sharp.
Iida	5	5·7.	Slight.	
Tokyo	5	9·8.	,,	
Kōfu	5	9·9.	,,	Gentle.
Mito	5	10·2.	,,	
Matsumoto ...	5	10·3.	,,	
Osaka	5	10·4.	,,	
Kumagai	5	14·0.	,,	
Wajima	5	14·5.	,,	
Yokohama	7	41·7.	Strong.	Accompanied by v.m. and a.s.
Mera	7	40·5.	Strong(r.w.).	Houses shaken.
Nagatsuro	7	42·5.	Strong.	Sharp, windows rattled.
Hamamatsu ...	7	41·3.	Weak.	Gentle.
Yokosuga	7	41 6.	,,	Duration long.
Tokyo	7	41·6.	,,	Gentle.
Kōfu	7	41·7.	,,	Duration long.
Numazu	7	42·8.	,,	Clock stopped.
Kyoto	7	43·3.	,,	Gentle.
Fukushima ...	7	21·0.	Slight.	
Iida	7	28·3.	,,	
Choshi	7	31·7.	,,	Gentle.
Tadotsu	7	41·4.	,,	
Hikone	7	41 5.	,,	
Mito	7	41·8.	,,	Gentle.
Maebashi	7	41·9.	,,	Duration long.
Osaka	7	42·0.	,,	
Yagi	7	42·3.	,,	Accompanied by v.m.
Gifu	7	42·4.	,,	
Matsuyama ...	7	43·0.	,,	Gentle.
Tsu	7	43·5.	,,	
Matsumoto ...	7	44·7.	,,	
Ishinomaki ...	7	45·3.	,,	

Yokohama	8h	3·5m.	Slight.	
Tokyo	8	4·0.	,,	
Mito	8	5·0.	,,	
Numazu	8	9·8.	,,	Duration long.
Yokohama	8	18·8.	,,	Gentle.
Nagatsuro	8	19·0.	,,	Sharp, windows ratted.
Tokyo	8	19·3.	,,	
Kumagai	8	19·4.	,,	
Kofu	8	19·5.	,,	Gentle.
Numazu	8	19·7.	,,	Sharp.
Hikone	8	20·0.	,,	
Osaka	8	20·1.	,,	
Fukushima	8	20·2.	,,	
Kyoto	8	20·5.	,,	
Mito	8	22 0.	,,	
Yokohama	10	38·2.	,,	
Tokyo	10	38·7.	,,	
Kofu	10	38·8.	,,	
Mito	10	40·0.	,,	

Nov. 6th.

Kofu	9h	4·0m.	Weak.	Accompanied by v.m.
Mera	9	12·7.	,,	Houses shaken.
Fukui	9	4·4.	Slight.	
Matsumoto	9	11·8.	,,	
Kumagai	9	12·9.	,,	
Yokohama	9	13·8.	,,	Gentle.
Tokyo	9	13·8.	,,	
Mito	9	14·6.	,,	
Numazu	9	14·2.	,,	Gentle.
Maebashi	9	14·3.	,,	,,
Fukushima	9	15·0.	,,	

The times of commencement at, and the epicentral distances from, the

different Milne H.P. Stations were as follows:—

Shide	...8h	7·5m,	91.°	San Fernando	...8h 28·3m, 106.°
Kew	...8	13·2,	90.	Bombay ...	...8 6·7, 59.
Toronto ...	.. 8	32·2,	99.	Batavia ...	...7 57·5, 48.
Victoria ...	.. 8	22·1,	73.		

The observations at Batavia and Shide related to P_2, while those at the others to certain phases in the p.p. From these data, we get 6·2 km. per sec. as the transit velocity of P_2.

Hongo register:—

Duration of the p.t. = 0·3m.

Duration of the p.p. = 21m.

Total duration was longer than 35 min., and less than 1h 30m. The e.p. was interfered by eqke. No. 80.

P_1, which arrived at 7h 41·3m, had an amp. of 0·2mm.

The p.p., which arrived at 7h 41·6m, was at first immeasurably great, the max. motion being roughly 38mm.

Eqke. No. 80. Nov. 5th 1900; 8h 19·7m.

This was an after-shock of the above-mentioned earthquake. Observations at the different Meteorological Stations have already been given.

Hongo register:—

The p.t. was interfered by the e.p. of the above-mentioned earthquake.

The p.p., which arrived at 8h 19·7m, had an amp. of 8·5mm. at the beginning. It lasted 2·5m.

Eqke. No. 87. Nov. 9th 1900; 17h 54·9m.

This earthquake occurred also in the sea-bottom as in the two previous earthquakes. Observations at the different Meteorological Stations were as follows:—

Nagatsuro ...	17h 54·5m.	Strong(r.w.)	
Yagi	17 25·7.	Weak.	Gentle.

Choshi	17h 53·0m.	Weak	Gentle.
Kumagai ...	17 55·0.	,,	Duration long.
Yokohama ...	17 55·3.	,,	Gentle.
Tokyo	17 55·4.	,,	,,
Kofu	17 55·9.	,,	Houses shaken, accompanied by v.m.
Numazu	17 56·0.	,,	Clock stopped.
Utsunomiya ...	17 52·6.	Slight.	
Nagoya	17 55·5.	,,	Gentle.
Osaka	17 56·1.	,,	
Gifu	17 56·9.	,,	Accompanied by v.m.
Fukui	17 57·4.	,,	Sharp.
Matsumoto ...	17 57·6.	,,	
Hikone	17 57·7.	,,	
Tadotsu	17 57·9.	,,	Accompanied by v.m.
Mito	17 58·7.	,,	Gentle.
Maebashi ...	18 3·8.	,,	Accompanied by v.m.
Fuhushima ...	18 17·4.	,,	

Preceding this earthquake by 1h 40m, another big one had occurred in Central America, so that these two were at certain stations observed simultaneously. The following are the observations relating rather to the present Japan earthquake:—

Shide	...18h 42·3m, 81.°	Bombay ...	...18h 20·6m, 60.°
Kew	...18 38·5, 79.	Madras ...	...18 14·2, 56.

Assuming that the 1st two observations related to P_3, and the last two to P_5, we get 4·4 and 3·56 km. per sec. as the transit velocity of P_3 and P_5 respectively.

Hongo register:—

Duration of the p.t. = 1·2m.

Duration of the p.p. = 15m.

Total duration = 3h 0m.

P_1, which arrived at 17h 54·9m, had an amp. of 0·6mm.

P_3, which arrived at 17h 56·1m, had an amp. of about 36·0mm.

Eqke. No. 88. Nov. 12th 1900; 1h 14·9m.

From the duration of the p.t. at Batavia and Tokyo, which were 11·4m and 10·5 respectively, we get a point long.=153° E, lat.=5° S, as the position of the seismic focus. The times of commencement at, and the epicentral distances from, the different Milne H.P. Stations were as follows:—

Kew	1h	28·8m,	81.°	Mauritius	1h	31·0m,	94.°
Toronto	1	27·1,	71.	Bombay	1	20·1,	81.
Victoria	1	22·2,	90.	Madras	1	18·1,	74.
San Fernando	1	25·8,	143.	Batavia	1	15·7,	46.
Cape of Good Hope	1	26·0,	123.				

From the graphic study of the relation between the times of arrival and the epicentral distances (Fig. 1,b), we get 1h 9·0m as the time of commencement at the origin, and 13·3 km. per sec. as the transit velocity of P_1.

Hongo register:—

Duration of the 1st p.t.=5·5m.

Duration of the 2nd p.t.=5·0m.

Total duration =2h 40m.

P_1, which arrived at 1h 14·9m, had an amp. of 0·1mm.

P_2, ,, 1h 20·4m, ,, 0·3mm.

P_3, ,, 1h 25·4m, ,, 1·5mm.

P_5, ,, 1h 30·4m, ,, 3·0mm.

P_6, ,, 1h 33·9m, ,, 1·2mm.

P_7, was not distinctly marked.

P_8, which arrived at 1h 42·7m, had an amp. of 0·6mm.

From the values of V_5 and the epicentral distance estimated from the duration of the p.t., we get.

$$V_3=4·2,\ V_6=3·02,\ \text{and}\ V_8=2·15.$$

Eqke. No. 91. Nov. 14th 1900; 21h 36·8m.

Observations at the different Meteorological Stations were as follows:—

Ishinomaki	21h	35·3m.	Weak.	Gentle.
Choshi	21	37·6.	,,	Houses shaken.
Utsunomiya	21	37·9.	,,	Gentle.
Tokyo	21	37·9.	,,	,,
Gifu	21	35·3.	Slight.	
Okayama	21	36·1.	,,	Gentle.
Mera	21	36·7.	,,	
Matsumoto	21	36·7.	,,	
Kanayama	21	37·0.	,,	
Aomori	21	37·8.	,,	
Kōfu	21	37·9.	,,	Duration long.
Hikone	21	37·9.	,,	
Yokohama	21	38·1.	,,	Gentle.
Fukui	21	38·1.	,,	
Mito	21	38·1.	,,	Gentle.
Osaka	21	38·2.	,,	
Akita	21	38·5.	,,	
Kumagai	21	38·7.	,,	
Yokosuga	21	38·8.	,,	
Maebashi	21	38·9.	,,	
Numazu	21	39·3.	,,	
Miyako	21	39·6.	,,	
Wajima	21	41·2.	,,	Gentle.
Matsumoto	21	43·0.	,,	
Fukushima	21	43·9.	,,	

This earthquake originated off the coast of the Province of Iwaki at a distance of about 400 km. from Tokyo. The phases P_2 and P_5 were registered at Batavia at 21h 51·1m and 22h 5·4m respectively, so that we get

$V_2=6{\cdot}6$, and $V_3=3{\cdot}30$.

Hongo register:—

Duration of the p.t.=0·9m.
Duration of the p.p.= 6m.
Total duration =1h 20m.

P_1, which arrived at 21h 36·8m, had an amp. of 0·3mm.
P_2, „ 21h 37·7m, „ 2·2mm.

Eqke. No. 99. Nov. 24th 1900; 7h 58·9m.

This earthquake originated off the south-eastern coast of Hokkaido at a point long.=152° E, lat.=47° N. Observations at the different Meteorological Stations were as follows:—

Nemuro ...	...7h 56·1m.	Slight.	Duration long.
Aomori ...	.. 7 57·9.	„	
Mito	...8 0·0.	„	
Akita	.. 8 0·8.	„	
Ishinomaki	...8 1·0.	„	
Kushiro ...	...8 1·3.	„	
Tokyo ...	.. 8 2·1.	„	
Kumagai ...	...8 2·5.	„	

The times of commencement at, and the epicentral distances from, the different Milne H.P. Stations were as follows:—

Shide	.. 8h 4·3m,	82.°	San Fernando ...	...8h 20·3m,	96.°
Kew ...	.. 8 8·7,	80.	Bombay	8 14·9,	70.
Toronto	.. 8 17·9,(?)	81.	Batavia	.. 8 6·7,	66.
Victoria	.. 8 5·4,	55.			

The observations at Toronto, San Fernando, and Bombay related probably to P_2, and those at the others to P_1. Thus we get 7h 57·2m as the time of occurrence at the origin and 12·9 and 7·4 km. per sec. as the transit velocities of P_1 and P_2 respectively. (See Fig. 1,b.)

Hongo register:—

Duration of the p.t.=3·2m.

Total duration=2h 40m.

P_1, which arrived at 7h 58·9m, had an amp. of 0·7mm.

P_3, ,, 8h 2·1m, ,, 1·4mm.

P_5, ,, 8h 4·2m, ,, 2·5mm.

A d.m. of an amp. of 5·5mm followed it and masked P_6.

P_7, which arrived at 8h 6·8m, had an amp. of 2·0mm.

P_8, ,, 8h 7·9m, ,, 1·8mm.

Many d.m. were registered among the stage of e.p., whose period of vibration was in general near to that of the pendulum boom itself.

From the values of V_5 and the epicentral distances estimated from the duration of p.t., we get

$$V_3=4·7,\ V_7=2·42,\ \text{and}\ V_8=2·17.$$

Eqke. No. 102. Dec. 3rd 1900; 14h 6·9m.

This earthquake originated probably in the Bonin curve about 450km. distant from Tokyo, as is to be inferred from the fact, that, notwithstanding the motion was large and the duration of the p.t. short, the earthquake was registered at no Meteorological Station.

Hongo register:—

Durations of the p.t.=1·0m.

Durations of the p.p.=13m.

Total duration =1h 0m.

P_1, which arrived at 14h 6·9m, had an amp. of 0·6mm.

P_3, ,, 14h 7·9m, ,, 3·0mm. It was followed by a d.m. of an amp. of 5·2mm.

Eqke. No. 103. Dec. 7th 1900; 7h 12·2m.

This earthquake originated probably off the coast of Noto Province. It was observed at Wajima at 7h 13·4m by means of an ordinary Gray-Milne type seismograph. The times of commencement at, and

the epicentral distances from, the different Milne H.P. Stations were as ollows:—

Shide	8h 5·0m.	Toronto	7h 41·0m.
Kew	7 49·0.	Victoria	7 44·1.

The observations at Kew and Victoria related to P_3, so that we get 4·0km. per sec. as the transit velocity of this phase.

Hongo register:—

Duration of the p.t. = 2·2m.

Total duration = 1h 0m.

P_1, which arrived at 7h 12·2m, had an amp. of 0·1mm.

A d.m. of an amp. of 1·5mm. appeared soon after the commencement and obscured the intial waves of the p.p.

P_3, which arrived at 7h 14·4m, was masked by the above-mentioned d.m.

P_5, which arrived at 7h 16·0m, had an amp. of 0 8mm.

Another d.m., which had an amp. of 2·3mm., was registered at 7h 17·6m.

Eqke. No. 106. Dec, 25th 1900; 5h 7·6m,

This earthquake originated probably near the Kurile Islands about a point long. = 150°E, lat. = 42°N at a distance about 11°·4 from Tokyo. The times of commencement at, and the epicentral distances from, the different Milne H.P. Stations were as follows:—

Shide	5h 16·9m,	84.°	Mauritius ..	5	23·5m(?), 105.°
Kew	5 16·4,	82.	Calcutta ..	5	13·1, 54.
Toronto	5 17·1,	84.	Bombay ..	5	14·0, 66.
Victoria	5 13·2,	58.	Madras ...	5	15·5, 66.
San Fernando	5 7·8(?),	100.	Batavia ...	5	15.0, 62.
Cape of Good Hope..	5 24·1,	141.			

Studying the above observations, with the exceptions of those at San Fernando and Mauritius, in relation to the epicentral distances, we

find a good example in which the linear relation between the *arcual* distance and the times taken in transit by the initial wave of p.t. is fairly represented. As it is to be seen in the illustration of seismogram at Hongo[1], the initial shock was well marked, so that it was definitely observed even at such a distant station as Cape of Good Hope, which is situated near the antipode of the seismic focus. In these cases the transit velocity can accurately be determined; while in ordinary cases, the p.t., which is minute, may be obscured at distant stations, giving a transit velocity less than the real value. By the graphical method, we get 5h 6·0m as the time of commencement at the origin and 14·7km. per sec. as the transit velocity of P_1. (See Fig. 1,b.)

Hongo register :—

Duration of the p.t. = 2·5m.
Duration of the p.p. = 23m.
Total duration = 2h 30m.

P_1, which arrived at 5h 7·6m, had an amp. of 1·2mm.
P_3, „ 5h 10·1m, „ 15·0mm.
P_5, „ 5h 11.8m, had a very large amplitude measuring not less than 30·0mm.

The subsequent phases could not be distinguished as the displacements were too large.

From the above observations, we get

$$V_1 = 13{\cdot}1,\ V_3 = 5{\cdot}1,\ \text{and}\ V_5 = 3{\cdot}55.$$

Eqke. No. 111. Jan. 7th 1901 ; 5h 21·6m.

This earthquake originated off the coast of Rikuzen. Observations at the different Meteorological Stations were as follows :—

Ishinomaki···	···5h 10·4m.	Weak.	Duration long.
Kanayama ···	···5 15·7.	„	Houses shaken.
Yokohama ···	·· 5 13·8.	Slight.	

1. Given in the *Reports (Japanese) of the Imp. Earthq. Inv. Comm.*, No. 35.

Fukushima ..	...5h 15·0m.	Slight.	
Miyako ...	.. 5 19·8.	,,	
Akita	...5 21·2.	,,	
Utsunomiya	...5 21·4.	,,	Gentle.
Yamagata ...	...5 21·5.	,,	
Kumagai ...	.. 5 21·6.	,,	Sharp.
Kofu	.. 5 21·7.	,,	,,
Maebashi ...	...5 21·7.	,,	
Tokyo	...5 21·8.	,,	
Nagoya ...	...5 21·8.	,,	
Niigata ...	.. 5 21·8.	,,	
Aomori ...	.. 5 21·9.	,,	Gentle.
Iida	.. 5 22·8.	,,	
Matsumoto ..	...5 22·9,	,,	

Hongo register :—

Duration of the p.t. = 1·0m.

Total duration = 12m.

P_1, which arrived at 5h 21·6m, was very slight.

P_3, ,, 5h 22·6m, had an amp. of 0·7mm.

Eqke. No. 113. Jan. 13th 1901 ; 22h 41·5m.

This earthquake originated off the coast of N.E. Japan. Observations at the different Meteorological Stations were as follows :—

Aomori ...	...22h 40·6m.	Strong(r.w.).	Sharp, houses shaken, accompanied by v.m.
Niigata ...	...22 34·1.	Weak.	Gentle.
Nemuro ...	...22 37·2.	,,	
Akita ...	...22 39·5.	,,	Duration long.
Mito	.. 22 42·2.	,,	Sharp, houses shaken.
Ishinomaki	...22 42·3.	,,	Houses shaken.
Kushiro ...	...22 42·8.	,,	Windows rattled.
Chōshi ...	.. 22 46·8.	,,	Sharp.

Sapporo ...	...22h 40 8m.	Slight.	Duration long.
Ishinomaki	.. 22 41·0.	,,	
Utsunomiya	.. 22 41·3.	,,	Gentle.
Fukushima	.. 22 41·7.	,,	Houses shaken.
Maebashi ..	.. 22 42·1.	,,	Gentle.
Tokyo ...	.. 22 42·5.	,,	
Kanayama	.. 22 42·8.	,,	
Miyako ...	.. 22 43·2.	,,	
Yamagata	.. 22 43·4.	,,	
Iida	...22 43·7.	,,	
Yokosuga ..	.. 22 43 7.	,,	
Kumagai ...	.. 22 46·9.	,,	
Hakodate ...	.. 22 38·7.	Weak.	Gentle.
Kamikawa	.. 22 33·0.	Slight.	,,

The times of commencement at, and the epicentral distances from, the different Milne H.P. Stations were as followes:—

Shide ...	..22h 7·0m.	Batavia ...	...22h 52·2m.
Kew	...23 2·3.	Strassburg ...	...23 3·3.
Bidston ...	...22 57·7.		

It has been difficult to draw any definite result from these observations.

Hongo register:—

Duration of the 1st p.t. = 1·0m.
Duration of the 2nd p.t. = 0·4m.
Duration of the p.p. = 8·0m.
Total duration = 1h 20m.

P_1, which arrived at 22h 41·5m, had an amp. of 0·4mm.
P_2, ,, 22h 42·5m. ,, 1·4mm.
P_3, ,, 22h 42·9m. ,, 1·4mm.
P_5, ,, 22h 44·2m. ,, 5·0mm.

Eqke. No. 116. Jan. 16th 1901 ; 2h 1·3m.

This earthquake originated in the Inland Sea (Setouchi). Observations at the different Meteorological Stations were as follows :—

Okayama	2h	0·3m.	Weak.	Accompanied by v.m.
Sakai	2	3·0.	,,	
Kōchi	1	59·1.	Slight.	
Tadotsu	2	0·2.	,,	Accompanied by v.m.
Kure	2	0·9.	,,	
Hikone	2	0·9.	,,	Gentle.
Fukui	2	1·0.	,,	
Yagi	2	1·0.	,,	
Miyazu	2	1·0.	,,	
Hiroshima	2	1·1.	,,	
Nagoya	2	1·4.	,,	Gentle.
Wakayama ...	2	1·7.	,,	
Wajima	2	2·3.	,,	Gentle.
Fukuoka	2	2·7.	,,	,,
Osaka	2	10·7.	,,	

Hongo register :—

Duration of the p.t. = 0·7m.
Duration of the p.t. = 5·5m.
Total duration = 22m.

P_1, which arrived at 2h 1·3m, was very slight.
P_3, ,, 2h 2·0m, had an amp. of 1·0mm.

Eqke. No. 117. Feb. 15th 1901, 8h 3·5m.

This earthquake originated in the Bay of Bengal or rather in the Indian Ocean off the west coast of Sumatra. Observations at the different Milne H.P. Stations were as follows :—

Shide ... ... 8h 29·1m. Victoria ... ... 8h 51·0m.

Kew ...	...8h 43·0m.	Cape of Good Hope	..8h 53·3m.
Bidston ...	...8 39·5.	Bombay	...8 3·2.
Edinburgh	.. 8 38·0.	Madras	.. 8 0·0.
Strassburg	.. 8 41·3.	Batavia	.. 8 15·8.
Toronto ...	...9 5·1.	Mauritius	.. 8 31·1.

These data being insufficient to determine the definite position of the epicentre, I have not estimated the time of occurrence at the origin and the transit velocity of the phases to which the above observations related.

Hongo register :—

Duration of the 1st p.t. = 4·2m.
Duration of the 2nd p.t. = 6·3m.
Duration of the p.p. = 11m.
Total duration = 55m.

P_1,	which arrived at	8h 3·5m,	was	very slight.
P_2,	,,	8h 7·7m,	had an amp. of	0·2mm.
P_3,	,,	8h 14·0m,	,,	0·3mm.
P_5,	,,	8h 19·0m,	,,	1·6mm.
P_6,	,,	8h 22·7m,	,,	1·0mm.
P_7,	,,	8h 26·7m,	,,	1·1mm.

Assuming the values of V_5 and epicentral distance (45°), we get

$$V_3 = 4{\cdot}1,\ V_6 = 2{\cdot}88, \text{ and } V_7 = 2{\cdot}53.$$

Eqke. No. 118. Feb. 18th 1901 ; 0h 25·8m.

This earthquake originated off the coast of Iwaki and Rikuzen. Observations at the different Meteorological Stations were as follows :—

Mito	...0h 23·3m.	Slight.	
Miyako ...	...0 26·3.	,,	Gentle.
Ishinomaki ..	.. 0 26·3.	,,	Duration long.
Fukushima...	.. 0 26·7.	,,	

Akita	...0h 26·9m.	Slight.
Aomori ...	...0 26·9.	,,
Tokyo	...0 28·7.	,,

Hongo register :—

Duration of the p.p. = 12m.

Total duration = 40m.

P_1, which arrived at 0h 25·8m, had an amp. of 0·3mm.

P_3, or rather P_5, which arrived at 0h 26·8m, had an amp. of 2·1mm., this phase being much larger than the others. The second maximum of an amp. of 1·8mm, which occurred at 0h 28·8m., was probably P_5.

Eqke. No. 119. Feb. 20th 1901 ; 9h 53·8m.

From the durations of p.t. at Batavia and Tokyo, the position of epicentre comes out to have been near the Philippine Archipelago.

The epicentral distances from, and the times of commencement at, the different Milne H.P. Stations were as follows :—

Kew ...	...10h 51·5m,	103.°	Cape of Good Hope	10h 10·5m,	108.°
Edinburgh	10 59·5,	103.	Batavia	9 51·4,	22.
Toronto	...10 18·1,	123.	Mauritius ...	10 4·1,	70.
Victoria	...10 18·0,	98.			

Assuming the observations at Toronto, Victoria, Cape of Good Hope, and Mauritius to have related to P_2, we get, by the graphical method,

$$V_2 = 7{\cdot}1.$$

Hongo register :—

Duration of the p.t. = 6·2m.

Total duration = 1h 0m.

P_1, which arrived at 9h 53·8m, had an amp. of 0·1mm.

P_3, ,, 10h 0·0m, ,, 0·4mm.

It was soon followed by a d.m. of an amp. of 1·2mm.

P_5, which arrived at 10th 3·4m, had an amp. of 0·6mm.

Assuming the values of V_5 and the epicentral distance we get

$$V_3 = 4{\cdot}3.$$

Eqke. No. 122. March 18th 1901; 23h 56·9m.

This earthquake originated off the southern coast of Hokkaido. Observations at the different Meteorological Stations were as follows:—

Nemuro ...	...23h 50·5m.	Slight.	Gentle.
Fukui ...	...23 55·2.	,,	
Fukushima	...23 55·2.	,,	
Mito	...23 56·8.	,,	
Tokyo ...	...23 56·9.	,,	
Kumagai ...	...23 58·0.	,,	

Hongo register:—

Duration of the p.t. = 1·7m.

Total duration = 15m.

P_1, which was slight, arrived at 23h 56·9m. This time was taken from the observation at the Central Meteorological Observatory. The watch keeqing register time having stopped on the occasion of the earthquake I have adopted this value though it related probably to the commencement of p.p.

P_3, which arrived at 23h 58·6m, had an amp. of 0·8mm.

The maximum phase of an amp. of 2·6mm. occurred 3m. later.

Eqke. No. 125. March 23rd 1901; 14h 22·3m.

Durations of the p.t. at Victoria and Tokyo having been 10·0m and 5·0m respectively, the epicentre was probably situated off the coast of Kamchatka. The times of commencement at, and the epicentral distances from, the different Milne H.P. Stations were as follows:—

Shide	14h	41·7m,		San Fernando	15h	8·3m,	93.°
Kew	14	55·6,		Cape of Good Hope	15	20·5,	143.
Bidston	14	33·7,	78.°	Calcutta	14	47·8,	58.
Edinburgh	14	52·0,		Madras	15	1·8,	71.
Strassburg	14	56·5,		Batavia	14	57·7,	69.
Toronto	14	30·0,	75.	Trinidad	15	28·0,	114.
Victoria	14	26·0.	48.				

Assuming the observations at Bidston, Toronto, and Victoria to have related to P_1, that at Shide to P_2, and that at Cape of Good Hope to P_3, we get, by the graphical method (Fig. 1,b.),

$$V_1=12{\cdot}5,\ V_2=6{\cdot}6,\ \text{and}\ V_3=4{\cdot}3.$$

Hongo register :—

Duration of the 1st p.t. = 2·2m.
Duration of the 2nd p.t. = 2·8m.
Duration of the p.p. = 6·0m.
Total duration = 1h 20m.

P_1,	which arrived at	14h 22·3m,	had an amp. of	0·4mm.
P_2,	„	14h 24·5m,	„	0·5mm.
P_3,	„	14h 27·3m,	„	0·7mm.
P_5,	„	14h 29·2m,	„	1·5mm.

P_5 was closely followed by a d.m. of an amp. of 2·0mm.

Eqke. No. 126. April 5th 1901 ; 22h 33·3m.

This earthquake originated off the coast of Hokkaido. The times of commencement at, and the epicentral distances from, the different Milne H.P. Stations were as follows :—

Shide	23h	21·0m.	Victoria	23h	38·1m.
Kew	23	13·4.	San Fernando	23	27·0.
Bidston	22	27·3.	Cairo	23	30·0.
Edinburgh	23	18·0.	Baltimore	23	22·0.
Strassburg	23	20·0.	Mauritius	22	14·0.

Phases, to which each of the above observations related having been doubtful, I have not deduced the transit velocity and the time of commencement at the origin.

Hongo register : —

Duration of the p.t. = 2·3m.
Total duration = 40m.

P_1, which arrived at 22h 33·3m, had an amp. of 0·2mm.
P_3, „ 22h 35·6m, „ 0·6mm.

Other phases were not distinctly marked.

Eqke. No. 127. April 5th 1901, 23h 34·0m.

This earthquake originated off the coast of Hokkaido. Observations at the different Meteorological Stations were as follows :—

Nemuro ...	...23h 31·5m.	Weak.	Gentle.
Ishinomaki	..23 34·1.	„	Duration long.
Aomori ...	...23 34·1.	„	Gentle.
Mito	..23 32·8.	Slight.	„
Tokachi ...	..23 33·1.	„	„
Sapporo ...	...23 33·1.	„	„
Kushiro ...	...23 33·5.	„	Duration long.
Kumagai ...	..23 33·7.	„	
Wajima ...	..23 34·2.	„	
Kanayama	...23 34·2.	„	Houses shaken.
Yokohama	...23 34·3.	„	Gentle.
Yamagata	...23 34·3.	„	
Tsu	...23 34·5.	„	
Miyako ...	...23 34·9.	„	
Maebashi ...	...23 35·7.	„	Sharp.
Kofu	..23 25·9.	„	Gentle.
Tokyo ...	..23 36·4.	„	
Iida	..23 36·7.	„	
Mito	...23 57·5.	„	

Akita ...	...23h 32·9m.	Weak Duration long.
Hakodate	...23 33·7.	,, Clock stopped.
Matsumoto	...23 39·6.	Slight.
Akita ...	...23 49·9.	,,
,, ...	...23 56·8.	,,

The times of commencement at, and the epicentral distances from, the different Milne H.P. Stations were as follows :—

Shide ...	.. 23h 56·0m,	84.°	Victoria	...24	4·0m, 62.°
Kew ...	.. 24 21·0,	84.	Cape of Good Hope	...23	53·1(?), 89.
Bidston ...	...24 21·3,	84.	Bombay	...23	42·1, 62.
Strassburg	.. 23 53·0(a), 24 26·0(b),	84.	Madras	.. 23	40·7, 60.
Toronto ..	.. 23 53·0,	89.	Batavia	...23	41·3, 57.

The observations at Bombay, Madras, and Batavia related to P_1, those at Shide, Strassburg (a), and Toronto to P_2, and those at Kew, Bidston, Strassburg (b), and Victoria to P_5. By the graphical method (Fig. 1,b), we get

$$V_1=12\cdot8,\ V_2=7\cdot2, \text{ and } V_5=3\cdot19.$$

Hongo register :—

Duration of the p.t. = 3·3m.

Duration of the p.p. = 45m.

Total duration = 2h 35m.

P_1, which arrived at 23h 34·0m, had an amp. of 0·3mm.

P_2, ,, 23h 37·3m, ,, 4·5mm.

P_5, ,, 23h 38·8m, ,, 15·0mm.

Eqke. No. 129. April 22nd 1901 ; 18h 9·5m.

This earthquake originated near Tokyo. Observations at the different Meteorological Stations were as follows :—

Yokohama ...	...18h 9·5m.	Strong(r.w.).	Sharp, accompanied by v.m.
Mito	..18 9·7.	Strong.	Sharp, accompanied by v.m., houses shaken.

Kumagai ...	...18h 10·8m.	Strong.	Accompanied by v.m., houses shaken.
Kanayama	...18 8·3.	Weak.	Houses shaken.
Utsunomiya	...18 9·0.	,,	Gentle.
Tokyo ...	18 9·5.	,,	Gentle, duration long.
Fukushima	...18 9·7.	,,	Houses shaken.
Yokosuga ...	...18 9·7.	,,	Duration long.
Numazu ...	..18 10·1.	,,	Gentle.
Kofu	..18 11·2.	,,	Accompanied by v.m., houses shaken.
Choshi ...	...18 12·4.	,,	Sharp.
Akita	..18 8·3.	Slight.	
Matsumoto	18 8·5.	,,	
Maebashi ...	...18 9·5.	,,	
Nagoya ...	..18 10·7.	,,	
Ishinomaki	..18 10·9.	,,	
Gifu	..18 11·6.	,,	
Hikone ...	...18 15·0.	,,	

Hongo register:—

Total duration = 11m.

As the seismic focus was very near Tokyo, the p.p. began suddenly being accompanied apparently by no p.t. The maximum displacement was registered at the beginning and had an amp. of 15mm.

Eqke. No. 131. May 30th 1901; 20h 10·6m.

This earthquake originated also near Tokyo. Observations at the different Meteorological Stations were as follows:—

Chōshi ...	...20h 9·6m.	Strong(r.w.).	Accompanied by v.m., houses shaken.
Yokosuga ...	...20 10·0.	Weak.	Accompanied by v.m.
Yokohama	...20 10·3.	,,	Gentle
Mito	...20 11·6.	,,	Sharp, houses shaken.
Nagano ...	...20 6·8.	Slight.	

Utsunomiya ...	20h 9·8m.	Slight.	Gentle.
Kumagai ...	20 10·2.	,,	
Tokyo ...	20 10·6.	,,	
Maebashi ...	20 10·7.	,,	Gentle.
Ishinomaki	20 11·4.	,,	
Kofu	20 11·7.	,,	Accompanied by v.m.
Kanayama	20 11·9.	,,	Houses shaken.
Tsu	20 12·0.	,,	
Fukushima	20 12·4.	,,	Houses shaken.
Gifu	20 12·6.	,,	Gentle.
Aomori ...	20 13·1.	,,	
Mito	20 19·0.	,,	

Hongo register:—

The p.t., which was masked by a.c., probably lasted a very short time, as the seismic focus was near Tokyo.

Duration of the p.p. = 6·0m.

Total duration was greater than 15m.

P_3, which arrived at 20h 10·6m, had an amp. of 14·0mm.

The e.p. was also masked by a.c.

Eqke. No. 132. May 14th 1901; 6h 51·0m.

This earthquake originated off the coast of Nemuro. Observations at the different Meteorological Stations were as follows:—

Nemuro ...	6h 49·1m.	Slight.	Gentle.
Fukushima ...	6 51·3.	,,	
Aomori ...	6 51·8.	,,	
Akita	6 52·8.	,,	
Ishinomaki ...	6 53·3.	,,	

The times of commencement at, and the epicentral distances from, the different Milne H.P. Stations were as follows:—

Shide ...	...7h 10·5m,	84.°	Strassburg ...	...7h 35·0m,	82.°
Kew ...	...7 10·4,		Toronto	...7 33·1,	86.
Bidston ...	...7 13·0,		Victoria	...7 6·0,	62.
Edinburgh	...7 11·0,		Cape of Good Hope	..8 11·1,	137.

The observations, at the four English Stations and Victoria related to P_2, so that we get 7·4 km. per sec. as the transit velocity. (See. Fig. 1,b.

Hongo register :—

Duration of the 1st p.t. = 0·9m.

Duration of the 2nd p.t. = 1·0m.

Total duration = 2h 0m.

P_1, which arrived at 6h 51·0m, had an amp. of 0·1mm.

P_2, ,, 6h 51·9m, ,, 0·8mm.

P_3, ,, 6h 52·9m, ,, 1·9mm.

P_5, ,, 6h 54·0m, ,, 2·8mm.

P_6 and P_7 were masked at 6h 56·2m by a d.m. of an amp. of 1·9mm.

P_8, which arrived at 6h 57·2m, had an amp. of 1·5mm.

From the values of V_5 and the epicentral distance estimated from the duration of the p.t., we get

$$V_3 = 4{\cdot}4, \text{ and } V_8 = 1{\cdot}93.$$

Eqke. No. 140. June 13th 1901 ; 3h 23·4m.

Taking the observations at the American stations and Tokyo into account, the epicentre seems to have been situated off the coast of Kurile Islands at a distance of about 18° from Tokyo. The times of commencement at, and the epicentral distances from, the different Milne H. P, Stations were as follows :—

Shide ...	...4h 6·6m.		Cape of Good Hope	...4h 46·6.	
Edinburgh	...4 0·0.		Bombay	...4 1·6.	
Victoria ...	...3 38·0.		Baltimore	...3 39·0.	
San Fernando	..4 15·4.				

The phases, to which the above observations related, having been doubtful, I have not deduced the transit velocity and the time of commencement at the origin.

Hongo register :—

Duration of the 1st p.t. = 2·4m.
Duration of the 2nd p.t. = 2·2m.
Total duration = 2h 0m.

P_1, which arrived at 3h 23·4m, was slight.
P_2, ,, 3h 25·8m, had an amp. of 0.2mm.
P_3, ,, 3h 28·0m, ,, 0·6mm.
P_5, ,, 3h 31·8m, ,, 0·9mm.

There occurred two d.m., one at 3h 35m and of an amp. of 1·4mm., and the other at 3h 38m and of an amp. of 1·2mm.

Eqke. No. 187. Aug. 9th 1901 ; 9h 24m.

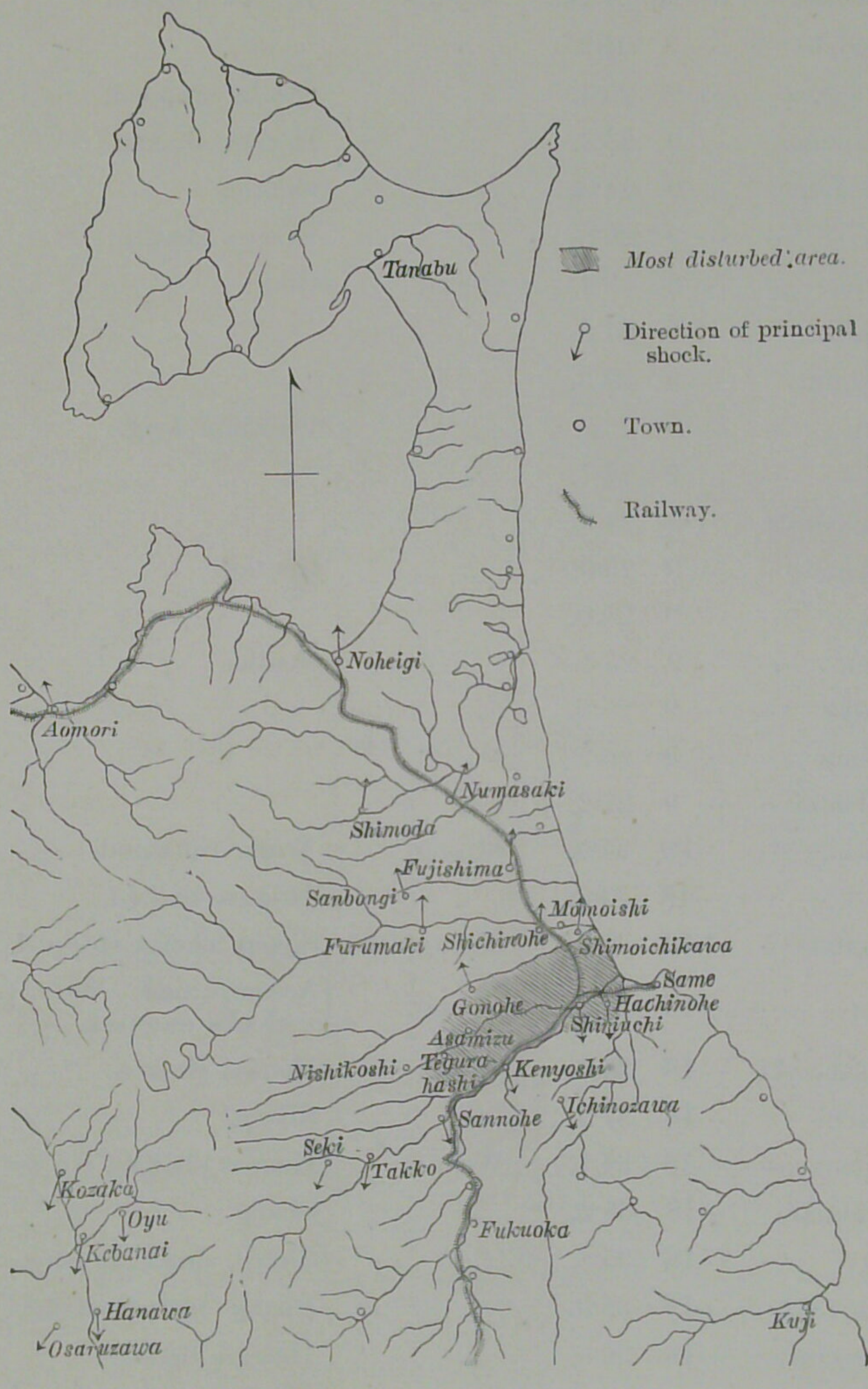
Eqke. No. 188. Aug. 9th 1901 ; 18h 34m.

These were severe Aomori earthquakes, which damaged some buildings and railway embankments around Hachinohe. The present writer visited the place soon after the occurrence of catastrophe, and studied the characters of seismic phenomenon. The earthquakes were unfortunately not registered by long-period H. P. seismographs at Tokyo, for in each of Omori's instruments the writing index was displaced off the face of record-receiver within a minute after the commencement, while our instrument was not working at the times of these disturbances.

Observations at the different Meteorological Stations were as follows :—

Miyako	9h 22·6m.	Strong.	Houses shaken.
Akita	9 24·3.	Strong (r.w).	Houses shaken, accompanied by v.m.
Aomori	9 25·1.	Strong.	Sharp, windows rattled, accompanied by e.s.
Niigata	9 25·9.	,,	

Ishinomaki ...	9h 24·1m.	Weak.	Houses shaken.
Hakodate ...	9 24·2.	,,	,,
Yokohama ...	9 25·4.	,,	Clocks stopped.
Kanayama ...	9 23·3.	,,	Houses shaken.
Fukushima ...	9 24·3.	,,	Gentle.
Mito	9 26·8.	,,	Houses shaken.
Nagano	9 9·4.	Slight.	Gentle.
Kushiro	9 21·9.	,,	,,
Yamagata ...	9 23·3.	,,	
Fukui	9 23·8.	,,	Duration long.
Iida	9 24·7.	,,	,,
Utsunomiya ...	9 24·9.	,,	
Kumagai	9 25·0.	,,	Gentle.
Tokyo	9 25·0.	,,	
Nemuro	9 25·4.	,,	Gentle.
Nagoya	9 25·8.	,,	,,
Wajima	9 26·2.	,,	
Maebashi	9 27·2.	,,	
Aomori	18 34·0.	Strong.	Walls fractured.
Miyako	18 34·5.	,,	Houses shaken.
Hakodate	18 34·7.	Strong(r.w.).	Sharp, clocks stopped.
Akita	18 35·1.	Strong.	Accompanied by v. m., clocks stopped.
Henashizaki ...	18 35·9.	Strong.	Houses shaken.
Tokachi	18 37·2.	,,	Sharp.
Sapporo	18 34·1.	Weak.	Houses shaken.
Ishinomaki ...	18 34·2.	,,	Sharp.
Tokyo	18 35·8.	,,	Sharp, duration long.
Kanayama ...	18 35·9.	,,	Sharp, houses shaken.
Yamagata	18 36·0.	,,	Houses shaken.
Mito	18 37·2.	,,	Sharp, accompanied by v.m., houses shaken.
Fukui	18 37·8.	,,	Sharp.
Yokohama ...	18 38·3.	,,	Clocks stopped.



Maebashi ...	...18h 38·5m.	Weak.	
Chōshi ...	...18 40·3.	,,	Gentle.
Fukushima	...18 41·2.	,,	Accompanied by v.m. and a.s., clocks stopped.
Kumagai ...	...18 41·9.	,,	Accompanied by v.m.
Nemuro ...	...18 33·1.	,,	Gentle.
Gifu	...18 31·3.	Slight.	Duration long.
Kamikawa	.. 18 35·5.	,,	Gentle.
Nagano ...	...18 36·1.	,,	
Iida	...18 36·5.	,,	Duration long.
Nagoya ...	...18 36 6.	,,	Gentle.
Utsunomiya	...18 37·1.	,,	

Besides these, there occurred many fore and after shocks, some of which were observed at a few meteorological stations near the seismic focus.

The origin of the two shocks was in a narrow band of country running from west to east in the low marshy district in the south-eastern part of the Province of Mutsu. The shaded area in the annexed figure indicates this band, about which lie the most damaged towns such as Shiriuchi, Hachinohe, &c.

Brick buildings of the railway station of Shiriuchi received severe damage, the walls facing NNW and SSE having been almost completely destroyed, while several wooden buildings in the vicinity were cracked, unroofed or twisted, as a whole. Besides five strow-roofed huts, which fell to the ground, there was a new woodenhouse, which, standing on an area of 14×8 sq. metres, fell to the south along the length of the foundation. Many of grave stones and a few bottles and lamps fell or were overturned toward south. As an instance, I mention the case of a suspended lamp in the Police Station, which was swung by the initial shock of the second earthquake toward due South, and then fell down. As regards the effect on land, cracks in river-banks, hill-sides, and high-roads were mostly found in a loose marshy district to the north of Shiriuchi. Railway embankment between Shiriuchi

and Shimoda at a distance of about 1 km. or two from the former station were loosened and lowered at four places, such that a work throughout 4 days and nights was necessary for reparation. Cracks of land were also numerous near Gonohe and Asamizu, and in a mountainous district between Tegurahashi and Nishikoshi, where land-slip of a total elongation of 260m occurred at 4 places, the debris covering roads and the river such that the water at last inundated and destroyed several acres of cultivated grounds.

In the town of Hachinohe two wooden houses were destroyed. On the loose ground of the local law office, there were formed three fissures, each running east and west and measuring 10–20cm. in width and 20m. in length, which totally damaged the buildings. Majority of grave stones were overturned toward north or south. The two-storied wooden building of the middle school, one of the largest in the epicentral district, received severe damage in windows, doors, and walls, which to the east or west, showing that the direction of principal shock was N-S.

In Furumaki, Sanbongi, and Gonohe plaster walls were cracked and grave stones overturned. An old inclining house at Takko fell down, though the shock was there less intense. At Noheiji and Aomori, larger buildings were more damaged than the smaller. The chimneys which had been erected through the roof of the Aomori Prefectual building were broken crushing the roof and walls, and thereby injuring a man. The fracturing of a chimney also took place at Kosaka mines about 50km. distant from the epicentre. There the shock was gentle, and caused only slight damage to buildings, yet the brick chimney, 48m. in height and standing on a chiff of 45m., broke into two at a point 21m. from the top, the upper part being overturned partly toward SSW but mostly toward NNE. The brick and the cementing material seemed to have been pretty good, but it is to be noted that the broken part was built in frosty season a few months after the erection of the lower part.

In the whole of the disturbed area, altogether 8 houses were ut-

terly destroyed, some 600 houses more or less damaged, and 17 persons were wounded.

The existence of the epicentral band is supported by the fact that the direction of the principal shock in or near this band or even at such a distant locality as Aomori was mostly N-S, though at certain districts this direction was deflected by an amount less than 20.° Further, the shock was most violent about Shiriuchi, the vertical movement having been felt there distinctly. On crossing this locality from south to north, a rapid variation of seismic intensity was to be observed, while on crossing in the direction perpendicular to the former the intensity variation was not marked for a long distance. The breadth of this band at the most disturbed area having been about 4 km, the depth of the seismic focus was probably about 3 km.[1]

If the earthquake disturbance was registered by Omori's H.P. seismograph at Tokyo, much interesting result would have been obtained with respect to the propagation of the different phases of earthquake waves, but unfortunately, the disturbance was too large to be recorded by the seismograph, as before noted. Within a minute, the writing index run off the smoked paper, showing just before the time an amp. of 14cm in the record. (The magnifying ratio of the index was 10.)

The times of commencement at, and the epicentral distances from, the different Milne H.P. Stations were as follows:—

Shide	...9h	36·8m,	18h 46·0m,	83.°
Kew	...9	36·0,	18 50·0(?),	82.
Bidston		—,	18 48·0,	83.
Edinburgh	...9	36·5,	18 47·0,	79.
Toronto	...9	47·0(no p.t.),	18 57·1(no p.t.),	89.
Victoria	...9	34·1,	18 44·1,	64.
San Fernando	9	38·1,	18 52·1,	99.

1. See A. Imamura: "*The depth of seismic focus*," the *Reports* (Japanese) *of the Earthq. Inv. Comm., No. 43.*

Cape of Good Hope	...	9h	45·5m,	18	57·0m,	134.°
Calcutta	...	9	32·4,	18	42·8,	51.
Bombay	...	9	34·4,	18	44·7,	61.
Madras	...	9	33·8,	18	53·5,	59.
Batavia	...	9	33·2,	18	42·4,	55.
Trinidad	...	9	36,	19	6,	128.

The graphic representation of the relation between the epicentral distances and the times taken in transit by P_1 gives 12·7 and 11·0km. per sec. as the transit velocity in the two earthquakes respectively. (See Fig. 1,b.)

Eqke. No. 189. Aug. 10th 1901; 10h 50·9m.

According to Prof. Milne, this earthquake originated in the Philippine Archipelago. The times of commencement at, and the epicentral distances from the different Milne H.P. Stations were as follows:—

Shide	11h	18·5m,	109.°	Victoria	11h	0·1m,	95.°
Kew	11	18·0,	107.	Cape of Good Hope	11	28·5,	110.
Bidston	11	19·3,	108.	Calcutta	11	0·8,	40.
Edinburgh	11	18·0,	108.	Batavia	10	48·0,	22.
Toronto	11	35·1,	125.				

The observations at Batavia and Victoria related to P_1, those at the English statians to P_2, and those at Victoria, Cape of Good Hope, and Toronto to P_3. By the graphical method (Fig. 1,b) we get 10h 45·2m as the time of occurrence at the origin, and 12·0, 5·2, and 4·7km. per sec. as the transit velocities of P_1, P_2, and P_3 respectively.

Hongo register:—

Duration of the 1st p.t. = 4·0m.

Duration of the 2nd p.t. = 3·5m.

Total duration = 53m.

P_1, which arrived at 10h 50·9m, was very slight.

P_2, „ 10h 54·9m, had an amp. of 0·5mm.

P_3, which arrived at 10h 58·4m, had an amp. af 0·6mm.
P_5, ,, 11h 1·1m, ,, 0·8mm.

A d.m. of an amp. of 3mm. occurred at 11h 4·3m and masked the two phases, P_6 and P_7.

P_8, which arrived at 11h 9·9m had an amp. of 0·6mm.

From the values of V_5 and the estimated epicentral distance, we get $V_3=3·9$, and $V_8=2·27$.

Eqke. No. 190. Aug. 11th 1901; 11h 28·4m.

This earthquake originated off the coast of N.E. Japan. Observations at the different Meteorological Stations were as follows:—

Miyako ...	...11h 27·8m.	Weak.	Accompanied by v.m.
Akita ...	...11 ·26·6.	Slight.	,,
Kumagai ...	...11 29·8.	,,	Duration long.
Fukushima	...11 30·5.	,,	

Hongo register:—
Duration of the p.t. = 1·0m.
Duration of the p.p. = 4·0m.
Total duration = 13m.

P_1, which arrived at 11h 28·4m, was slight.
P_3, ,, 11h 29·4m, had an amp. of 0·4mm.

Eqke. No. 191. Aug. 11th 1901; 14h 35·2m.

According to Prof. Milne, this earthquake originated in the Marianne Islands. The times of commencement at, and the epicentral distances from, the different Milne H.P. Stations were as follows:—

Shide	...15h 9·4m,	103.°	Cape of Good Hope ...15h 39·0m, 130.°
Kew	...15 34·2,	102.	Calcutta ... ...14 51·5, 52.
Bidston	...15 12·0,	103.	Madras ... ...15 15·2 (?), 63.
Edinburgh	15 22·0,	102.	Batavia ... ...14 38·3, 45.
Victoria	...14 51·2,	76.	

The observations at Batavia related to P_1, while those at Shide, Bidston, and Calcutta related probably to P_3. By the graphical method (Fig. 1,b), we get $V_3=5{\cdot}1$.

Hongo register :—

Duration of the p.t. $=7{\cdot}7$m.
Total duration $=1$h 30m.
P_1, which arrived at 14h 35·2m, was very slight.
P_3, ,, 14h 42·9m, had an amp. of 0·3mm.
P_5, ,, 14h 48·2m, ,, 0·4mm.
P_6, ,, 14h 52·5m, ,, 0·3mm.

P_6 was followed by 6 d.m., the largest of which took place at 14h 58·2m, and had an amp. of 1·1mm.

Eqke. No. 193. Sept. 24th 1901 ; 8h 6·2m.

This earthquake originated probably near the Philippine Islands, but the data are not enough to determine the definite position of the epicentre. Observations at Milne H.P. Stations were as follows :—

Bidston ...	.. 8h 28 0m.	Bombay ...	.. 8h 18·1m.
Edinburgh ...	.. 8 29·5.	Madras ...	.. 8 17·3.
Victoria ...	...8 13·1.	Batavia ...	.. 7(?) 4·5.
Calcutta ...	...8 10·8.		

Hongo register :—

Duration of the p.t. $=7{\cdot}9$m.
Duration of the p.p. $=10$m.
Total duration $=45$m.

P_1, which arrived at 8h 6·2m, was very slight. This phase was followed by a series of waves, which increased their magnitude gradually but rapidly until an amp. of 0·3mm was reached at 8h 10·2m.

P_3, which arrived at 8h 14·1m, had an amp. of 0·9mm.

Eqke. No. 199. Oct. 10th 1901 ; 10h 29·9m.

Observations at the different Meteorological Stations were as follows :—

Fukui	10h 23·2m.	Slight.	
Utsunomiya ...	10 25·1.	Slight.	Gentle.
Tokyo	10 27·2.	,,	
Kumagai ...	10 27·5.	,,	
Yokohama ...	10 28·4.	,,	

Hongo register :—

Duration of the p.t. = 1·7m.

Duration of the p.p. = 8m.

Total duration = 32m.

P_1, which arrived at 10h 29·9m, had an amp. of 0·1mm.

P_3, ,, 10h 31·6m, ,, 0·6mm.

Two min. later, a d.m. of an amp. of 0·9mm. occurred.

Eqke. No. 200. Oct. 19th 1901 ; 10h 6·0m.

This earthquake originated in the Philippine Islands.[1] Observations at the different Milne H.P. Stations were as follows :—

Shide	10h 19·6m.		San Fernando ...	9h	51·2m.
Kew	10	23·8.	Bombay	9	14·9.
Edinburgh ...	10	9·5.	Madras	10	10·6.
Toronto	10	9·0.	Batavia	9	1·7, 58·7.
Victoria	10	1·1.			

As it is to be seen in the observation at Batavia, another earthquake of moderate magnitude occurred about an hour before, so that some of the above observations related to this first earthquake.

Hongo register :—

Duration of the p.t. = 8·2m.

Duration of the p.p. = 16m.

Total duration = 1h 10m.

P_1, which arrived at 10h 6·0m, had an amp. of 0·1mm.

P_3, ,, 10h 14·2m, ,, 1·1mm.

P_5, ,, 10h 18·0m, ,, 1·1mm.

P_8, ,, 10h 24·8m, ,, 1·1mm.

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1. See *Boletin Mensual, Obs. de Manila*, Ano 1901.

The last three phases predominated, the other phases being comparatively slight.

The epicentral distance from Tokyo being 3100 km, which is nearly equal to the value from the duration of the p.t., the transit velocities of P_3 and P_8 come out, on assuming the value of V_5, as follows:—

$V_3=4{\cdot}4$, and $V_8=2{\cdot}30$.

Eqke. No. 209. Dec. 14th 1901; 23h 2·6m.

This earthquake originated in the vicinity of Manila, where the disturbance was violent. A full account is given in the Bulletin of Manila Central Observatory.[1] The seismic focus was at a point *long.* 121°E, *lat.* 15°N, and the time of commencement at the epicentre 22h 58·3m. The times of commencement at, and the epicentral distances from, the different Milne H.P. Stations were as follows:—

Shide	23h	11·4m,	98.°	Calcutta	23h	4·1m,	31.°
Kew	23	15·7,	97.	Bombay	23	6·7,	46.
Edinburgh	23	15·0,	95.	Madras	23	5·0,	49.
Toronto	23	20·1,	120.	Batavia	23	2·7,	25.
Victoria	23	11·0,	96.	Baltimore	23	19·2,	127.
San Fernando	23	12·2,	109.	Cape of Good Hope.	23	15·6,	108.
Trinidad	23	19,	155.				

To these we may add the observations at the following seismic stations in the different parts of the world;—

Irkutsk	23h	5·2m,	40.°	Rocca di papa	23h	10·9m,	93.°
Manila	82	58·3,	0.	Rome	23	10·8,	94.
Hamburg	23	10·5,	90.	Quarto di Castello	23	10·9,	94.
Laibach	23	10·8,	91.	Florence	23	10·6,	94.
Pola	23	10·5,	92.	Strassburg	23	10·6,	94.
Padua	23	10·7,	93.	Pavia	23	10·1,	94.
Catania	23	10·5,	93.				

1. Bulletins for Dec. 1901 and for Dec. 1902.

The graphic representation of these times and epicentral distances shows that the transit velocity for the first 50° was 11·5 km. per sec., while in average it was 13·6 km. per sec. (See Fig. 1,b.)

Hongo register :—

Duration of the 1st p.t. = 2·9m.
Duration of the 2nd p.t. = 3·9m.
Duration of the p.p. = 15m.
Total duration = 1h 40m.

P_1, which arrived at 23h 2·6m, had an amp. of 0·5mm.

It was definitely marked among slight movements due to a.c.

P_2, which arrived at 23h 5·5m, had an amp. of 1·2mm.
P_3, ,, 23h 9·4m, ,, 1·4mm.
P_5, ,, 23 12·7m, ,, 6·0mm.

This wave was much larger than the movements in the other phases.

P_6, which arrived at 23h 16·3m, had an amp. of 2·5mm.

P_7 was not distinctly marked.

P_8, which arrived at 23h 20·2m, had an amp. of 3·0mm.

The epicentral distance having been 3000km, we get
$V_1 = 11·6$, $V_2 = 6·9$, $V_3 = 4·5$, $V_5 = 3·47$, $V_6 = 2·77$, and $V_8 = 2·28$.

Eqke. No. 217. Jan. 30th 1902; 14h 0m.

This was a strong earthquake which originated off the southern coast of Hakkaido. Unfortunately it was not registered by our instrument, but it will be interesting to see how it was registered at the different Milne H.P. Stations. Observations at the different Meteorological Stations were as follows :—

Tokachi	14h 0·1m.	Strong.	Accompanied by v.m.
Aomori	14 0·8.	,,	Sharp, houses shaken.
Miyako	14 0·8.	,,	Accompanied by v.m., houses shaken.
Akita	14 1·2.	,,	,,

Kushiro ...	...14h	0·4m.	Weak.	Houses shaken.
Utsunomiya	...14	0·7.	„	Duration long.
Hakodate	...14	0·8.	„	Sharp, houses shaken.
Ishinomaki	...14	1·3.	„	Sharp, liquid in vessels overflowed.
Mito	...14	1·3.	„	Accompanied by v.m., houses shaken.
Yamagata ..	14	1·3.	„	Houses shaken.
Kumagai ..	.. 14	1·8.	„	Gentle.
Kanayama	...14	2·1.	„	Duration long.
Henashizaki	...14	10·0.	„	Windows rattled.
Chōshi ...	...14	0·9.	Slight	Gentle.
Kamikawa	...14	0·9.	„	„
Nagano ...	...14	1·2.	„	Duration long.
Tokyo ...	...14	1·9.	„	„
Maebashi ..	...14	1·9.	„	„
Niigata ...	...14	2·0.	„	Windows rattled.
Sapporo ...	...14	2·0.	„	Houses shaken.
Nagoya ...	...14	2·4.	„	Gentle.
Numazu ...	...14	2·9.	„	„
Matsumoto	...14	3·3.	„	

Thus the time of occurrence was about 4h 0m at the origin. The times of commencement at, and the epicentral distances from, the different Milne H.P. Stations were as follows :—

Shide	...14h	9·5m,	82.°	Calcutta ...	...14h	8·0m,	48.°
Kew	...14	23·0,	81.	Bombay ...	...14	10·1,	62.
Bidston ...	...14	21·5,	81.	Madras ...	.. 14	10·6,	60.
Edinburgh	...14	23·0,	79.	Batavia ...	.. 14	10·0,	56.
Toronto ...	...14	24·2,	88.	Baltimore ...	.. 14	25·1,	92.
Victoria ...	...14	10·2,	63.	Christchurch	...14	23·2,	88.

The observations at the stations whose epicentral distances were greater than 70° related probably to P_2, with the exception of that at Shide,

which like those at the nearer stations related to P_1. (See Fig. 1,b.) In so assuming, we get

$$V_1 = 11.7 \text{ and } V_2 = 6{\cdot}7.$$

Eqke. No. 217''. Jan. 31st 1902; 1h 42m.

This earthquake, which originated off the southern coast of Hokkaido, was also not recorded by our instrument. Observations at the different Meteorological Stations were as follows:—

Aomori	1h 42·2m.	Strong.	Sharp, windows rattled.
Sapporo	1 41·9.	Weak.	Gentle.
Ishinomaki	1 42·0.	,,	
Tokachi	1 42·6.	,,	
Miyako	1 42·6.	,,	Accompanied by v.m., houses shaken.
Akita	1 42·8.	,,	
Matsumoto	1 42·0.	Slight.	Duration long.
Mito	1 42·0.	,,	Gentle.
Nemuro	1 42·8.	,,	Duration long.
Kumagai	1 42·9.	,,	,,
Nagano	1 43·1.	,,	Gentle.
Chōshi	1 43·3.	,,	
Tokyo	1 43·4.	,,	
Kanayama	1 43.4.	,,	
Yokohama	1 43·6.	,,	
Yamagata	1 44·0.	,,	
Maebashi	1 44·2.	,,	
Utsunomiya ...	1 44·5.	,,	Gentle.
Fukuoka	1 59·7.	,,	
Kamikawa	1 43·2.	,,	Gentle.
Fukushima	1 43·2.	,,	

Observations at Milne H.P. Stations were as follows:—

Shide	...	...1h	53·1m, 82.°	Victoria	... ...	...2h	2·6m, 63.°
Kew...	...	...2	3·0, 81.	Cape of Good Hope		...2	48·0, 134.
Bidston	...	.. 2	2·7, 81.	Calcutta	... ...	.. 2	1·9, 48.
Edinburgh		...2	4·0, 79.	Bombay	... ...	...1	51·6, 62.
Toronto	...	...2	5·0, 88.	Madras	... ...	...1	59·5, 60.

The observations at Shide and Bombay related to P_1, while the others with the exceptions of those at Cape of Good Hope and Madras related to P_2. (See Fig. 1,c.) Thence we get

$$V_1=13{\cdot}0 \text{ and } V_2=6{\cdot}7.$$

Eqke. No. 221. Feb. 20th 1902; 1h 49·7m.

This earthquake originated near Tokyo. Observations at the different Meteorological Stations were as follows:—

Yokohama	.. 10h 49·8m.	Weak.	Gentle.
Tokyo ...	...10 49·9.	Weak(r.s.).	
Mera	.. 10 50·5.	,,	Gentle.
Utsunomiya	.. 10 45·8.	Slight.	,,
Niigata ...	...10 49·5.	,,	
Numazu ...	...10 49·9.	,,	Gentle.
Wajima ...	...10 50·0.	,,	Duration long.
Mito	..10 50·0.	,,	Gentle.
Nagano ...	...10 50·1.	,,	
Yokohama	.. 10 50·1.	,,	Gentle.
Kōfu ...	...10 50·2.	,,	
Nagoya ...	.. 10 50·2.	,,	,,
Maebashi ...	...10 50·4.	,,	
Choshi ...	.. 10 50·4.	,,	
Fukushima	...10 51·0.	,,	
Kanayama	...10 51·0.	,,	
Yagi	...10 51·5.	,,	
Akita ...	.. 10 52·5.	,,	
Kumagai ..	.. 10 55·0.	,,	
Fukui ...	...10 59·5.	,,	

Hongo register :—

Duration of the p.t. = 0·5m.

Duration of the p.p. = 5.0m.

Total duration = 17m.

P_1, which arrived at 1h 49·7m, had an amp. of 0·2mm.

P_3, which arrived at 1h 50·2m, had an amp. of 6·0mm. The maximum phase was registered 1min. later, and had an amp. of 8·0mm.

Eqke. No. 222. Feb. 20th 1902; 15th 40·2m.

This earthquake originated in the N.E. Japan. Observations at the different Milne H.P. Stations were as follows :—

Aomori	15h 34·6m.	Strong(r.w.).	Accompanied by v. m., houses shaken.
Yamagata	...15 39·3.	Weak.	Houses shaken.
Henashizaki	...15 39·7.	,,	Sharp, windows rattled.
Akita ...	...15 38·1.	Weak (r.s.).	Accompanied by v.m.
Hakodate ...	...15 38·2.	,,	Houses shaken.
Miyako ...	...15 38·3.	,,	Sharp, houses shaken.
Ishinomaki	.. 15 38·5.	,,	Houses shaken.
Yokohama	...15 40·9.	,,	Gentle.
Kanayama	...15 39·2.	Slight.	
Tokachi ...	...15 38·3.	,,	Gentle.
Fukushima	...15 38·9.	,,	
Nagano ...	...15 39·1.	,,	Gentle.
Sapporo ...	...15 39·2.	,,	Duration long.
Wajima ...	...15 39·5.	,,	
Fukui ...	...15 40·1.	,,	
Tokyo ...	...15 40·5.	,,	
Maebashi ...	...15 40·7.	,,	Gentle.
Choshi ...	...15 40·8.	,,	
Kōfu ...	...15 42·5.	,,	Gentle.

Hongo register :—

Duration of the p.t. = 1·0m.

Duration of the p.p. = 5·5m.
Total duration = 25m.
P_1, which arrived at 15h 40·2m, had an amp. of 0·1mm.
P_3, ,, 15h 41·2m, ,, 0·7mm.
The maximum phase of an amp. of 2·0mm was registered at 15h 42·9m.

Eqke. No. 227. March 1st 1902; 0h 15·9m.

This earthquake originated off the Pacific coast of Formosa. Observations at the Meteorological Stations near the origin were as follows :—

Taihoku	0h 13.9m.	Strong(r.w.).	Houses shaken.
Taito	0 1·5.	Slight.	Windows rattled.
Ishigakijima ...	0 16·1.	,,	Gentle.
Tainan	0 7.1.	,,	Sharp.

Putting much weight upon the observation at Taihoku, I assume 0h 13·0m as the time of occurrence at the origin. The times of commencement at, and the epicentral distances from, the different Milne H.P. Stations were as follows :—

Shide	1h	9·4m,		San Fernando ..	1h	8·4m,	102.°
Do (Yarrow pls.)	0	52·9,	89.°	Calcutta	0	24·7,	30.
	1	0·1,		Bombay	0	21·9,	45.
Kew	1	9·2,	88.	Batavia	0	23·2,	34.
Bidston	1	5·0,	89.	Christchurch ...	0	34·6,	81.
Edinburgh ..	0	50·0,	87.				

Of these observations, those at Edinburgh, Calcutta, Batavia, and Shide (1st entry to Yarrow pls.) related to P_3, while the others with the exceptions of those at Christchurch and Bombay related to some phases between P_5 and P_7. The graphic study of the observations relating to P_3, gives for the latter a transit velocity of 4·2 km. per sec.

Hongo register :—
Duration of the p.t. = 4·0m.

Total duration was greater than 2h 15m.

P_1, which arrived at 0h 15·9m, was very slight such that its existence could only be ascertained when the seismogram was compared with that given by Omori's H.P.

P_3, which arrived at 0h 19·9m, had an amp. of 0·3mm.

P_5, „ 0h 21·8m, „ 0·6mm.

At 0h 25·4m, large waves, followed by a d.m. of an amp. of 1·7m and lasting 5min., were registered. The e.p. was only partly observed as it was the time of winding the clock.

From the values of V_5 and the epicentral distance measuring 18°·5, we get

$$V_3 = 4{\cdot}0.$$

Eqke. No. 228. March 17th 1902; 1h 59·4m.

This earthquake originated at a distance of about 100km. off the coast of Hitachi. Observations at the different Meteorological Stations were as follows :—

Mito	...1h 57·7.m	Slight.	
Tokyo	...1 59·4.	„	

Hongo register :--

Duration of the p.t. = 0·5m.

Total duration = 10m.

P_1, which arrived at 1h 59·4m, was very slight.

P_3, „ 1h 59·9m, had an amp. of 1·2mm.

Eqke. No. 237. March 25th 1902; 5h 35·3m.

This earthquake originated near Tokyo. Observations at the different Meteorological Stations were as follows :—

Chōshi ...	...5h 34·6m.	Strong(r.w.).	Sharp, accompanied by v.m., clocks stopped.
Mito	...5 34·8.	Weak.	Sharp, accompanied by v.m., houses shaken.
Yokohama ...	.. 5 35·8.	„	Gentle.

Wajima ...	...5h 34·0m.	Slight.	Duration long.
Yakosuga ...	.. 5 34·0.	„	
Utsunomiya	.. 5 34·8.	„	Sharp.
Kumagai ...	.. 5 34·9.	„	
Tokyo	.. 5 34·9.	„	
Fukushima	...5 35·2.	„	
Maebashi ...	...5 35·3.	„	
Numazu ...	...5 35·5.	„	Gentle.
Kanayama ...	...5 35·8.	„	
Tsu	.. 5 36·1.	„	Gentle.
Akita	.. 5 36·2.	„	
Iida	...5 35·3.	„	Duration long.
Matsumoto ...	...5 35·7.	„	
Gifu	.. 5 37·4.	„	

Hongo register :—

Duration of the p.t. = 0·3m.

Total duration = 10m.

P_1, which arrived at 5h 35·3m, had an amp. of 0·3mm.

P_3. „ 5h 35·6m, had the max. amp. of 4·2mm.

Eqke. No. 238. April 11th 1902 ; 23h 55·1m.

This earthquake, which originated near Japan, probably in th Bonin curve, was followed by another which occurred about 1 hour later. The duration of p.t., given by the seismograms of Omori's H.P. at Tokyo and Osaka having been 4·0m and 4·4m respectively, we get a point *long.* 150°E, *lat.* 23°N, for the position of the epicentre.

The observations at the different Milne H.P. were as follows :—

Shide	...24h 16·9m,	102.°	Cape of Good Hope	24h 17·3m,	135.°
Kew ...	...24 17·6,	102.°	Calcutta	.. 23 59·9,	55.
Edinburgh	24 19,	102.°	Batavia	...24 16·3,	50.
Toronto	...24 18·3,	102.	Baltimore	.. ...24 17·7,	105.
Victoria	...24 51·6,	72.	Perth	...24 44,	62.

Of the above observations those at the English stations, Baltimore, and Toronto related to P_2, for whose transit velocity we get 7·7 km. per sec.

Hongo register :—

Duration of the p.t. = 4·5m. The value given by Omori's instrument was 4·0m.

Total duration = 27m.

P_1, which arrived at 23h 55·1m, was very slight.

P_3, ,, 23h 59·6m, had an amp. of 0·3mm. It was followed by a d.m. of an amp. of 1·8mm., the waves corresponding to those in Omori's H.P. seismogram having a period of 15 sec. and an amp. not exceeding 0·6mm.

P_5, which arrived at 24h 2·7m, had an amp. of 0·6mm.

P_6, ,, 24h 4·6m, ,, 0·4mm.

P_7, ,, 24h 6·4m, ,, 0·4mm.

P_8, ,, 24h 8·4m, ,, 0·2mm.

The epicentral distance deduced from the duration of the p.t. being 1900km, we get on assuming the value of V_5 the following results :—

$$V_3 = 4·9,\ V_6 = 2·75,\ V_7 = 2·38,\ V_8 = 2·07.$$

Eqke. No. 239. April 19th 1902 ; 2h 38·8m.

This was a large Guatemala earthquake. A full discussion of the observations at the different Milne H.P. Stations will be given in Chapter V ; here, I will only describe how it was registered at Hongo.

Hongo register (Fig. 5) :—

Duration of the 1st p.t. = 14·2m.

Duration of the 2nd p.t. = 11·5m.

Total duration = 2h 50m.

As regards the period of earthquake waves, we have here a remarkable example. In Omori's H.P. Seismograph at Hitotsubashi, the p.t. was recorded as one consisting of slow waves of period of about 15 sec., such waves having been most frequent in the latter part of the

1st p.t. and in the whole stage of the 2nd p.t., while the waves in the p.p. were of still longer period.

P_1, which arrived at 2h 38·8m, was less than 0·1mm.

P_2, ,, 2h 53·0m, had an amp. of 0·5mm. It was immediately followed by a d.m. of an amp. of 2·4mm. Two other d.m. of a considerable magnitude were recorded at 2h 54·5m and 2h 57·0m.

P_3, which arrived at 3h 4·5m, had an amp. of 1·2mm.

P_5, ,, 3h 24·3m, ,, 0·6mm.

P_7, ,, 3h 49·0m, ,, 0·5mm.

P_8, ,, 4h 2·8m, ,, 0·3mm.

P_3', which is assumed to be the 3rd phase propagated along the major arc of the great circle, was registered at 4h 8·0m. Its amp. was about 0·3mm.

As the time of occurrence at the origin was 2h 26·0m, and the epicentral distance from Tokyo 12230km, we get

$V_1=15·8$, $V_2=7·5$, $V_3=5·3$, $V_5=3·50$, $V_7=2·46$, $V_8=2·12$, and $V_3'=5·4$.

Eqke. No. 242. May 2nd 1902; 11h 32·0m.

This earthquake originated off the coast of N.E. Japan. Observations at the different Meteorological Stations were as follows:—

Aomori ...	...11h	31·8m.	Weak(r.s.). Accompanied by v.m.
Ishinomaki ..	11	31·5.	Slight.
Akita ...	...11	37·0.	,,
Wajima ...	...11	31·4.	Slight(unfelt). Duration long.
Mito	...11	31·5.	,,
Tokyo ...	...11	33·1.	,,

The times of commencement at, and the epicentral distances from, the different Milne H.P. Stations were as follows:—

Shide	11h	55·1m, 84.°	Bidston ... ..11h 52·3m, 82.°
Kew	11	58·5, 82.	Edinburgh ... ...11 52·0, 80.

Calcutta ...	...11h 46·3m, 47.°	Baltimore ...	.. 12h 27·6m, 95.°
Bombay ...	...11 51·7, 62.	Christchurch	...11 55·0, 87.

These observations, except that at Baltimore, related to P_2, and give a transit velocity of 6·4km. per sec.

Hongo register :—

Duration of the 1st p.t. = 0·9mm.
Duration of the 2nd p.t. = 0·8mm.
Duration of the p.p. = 12m.
Total duration = 1h 50m.

P_1, which arrived at 11h 32·0m, had an amp. of 0·3mm.
P_2, ,, 11h 32·9m, ,, 1·6mm.
P_3, ,, 11h 33·7m, ,, 16·0mm.
P_5, ,, 11h 35·2m, was the largest among all the stages, and had an amp. of 18·0mm.

Eqke. No. 243. May 8th 1902; 2h 20·9m.

This earthquake originated off the south-eastern coast of Kūshū Island at a distance of about 9° from Tokyo. Observations at the different Meteorological Stations were as follows :—

Satanomisaki	...2h 10·3m.	Weak.	Duration long.
Miyazaki ...	...2 20·0.	,,	Houses shaken.
Kagoshima ...	...2 19·3.	Weak(r.s.).	Accompanied by v. m., houses shaken.
Wajima ...	.. 2 21·2.	Slight.	
Oshima ...	.. 2 22·0.	,,	
Fukuoka ...	.. 2 20·0.	Slight(unfelt).	
Matsuyama	.. 2 22·1.	,,	
Kumamoto ...	...2 19 9.	,,	Duration long.
Saga	...2 20·6.	,,	
Hiroshima ...	...2 21·0.	,,	

The times of commencement at, and the epicentral distances from, the different Milne H.P. Stations were as follows :—

Shide	...	..	2h 49·5m, 86.°	Calcutta	..	...	...2h 36·1m, 38.°
Kew	...	...	..3 8·5(?), 85.	Bombay	...	...	...2 46·1, 54.
Bidston	...	...	3 0·4, 86.	Batavia	..	...	. 2 33·7, 43.
Edinburgh	...	..	3 0.0, 85.	Christchurch	..	..	2 55·0, 77.

These observations, except the first two, related probably to P_3, from which we get a transit velocity of 4·1km. per sec.

Hongo register :—

Duration of the p.t. = 2·7m.

Duration of the p.p. = 7·0m.

Total duration = 1h 10m.

P_1, which arrived at 2h 20·9m, was very slight.

P_3, ., 2h 23·6m, had an amp. of 0·6mm.

P_5, ,. 2h 25·0m, ,, 5·0mm.

Assuming the value of V_5, we get $V_3 = 4·7$.

Eqke. No. 245. May 25th 1902 ; 9h 6·7m.

This earthquake originated off the Pacific coast of Hokkaido. Observations at the different Meteorological Stations were as follows :—

Kushiro	...	.. 9h 1·9m.	Strong(r.w.).	Sharp, houses shaken.
Tokachi	...	...9 2·2.	Weak.	Sharp.
Nemuro	...	.. 9 1·3.	Weak(r.s.).	Duration long.
Abashiri	...	...9 1·1.	Slight.	
Sapporo	...	.. 9 2·8.	,,	Gentle.
Aomori	...	...9 3·1.	,,	Sharp.
Miyako	..	... .. 9 3·2.	,,	Sharp, accompanied by v.m.
Wajima	...	...9 4·1.	,,	
Mito	...	... .. 9 4·5.	,,	Sharp.
Ishinomaki	...	...9 3·2.	Slight(unfelt).	
Fukushima	...	...9 4·2.	,,	
Akita	...	... ...9 4·8.	,,	
Kumagai	...	...9 5·2.	,,	
Tokyo	...	... ...9 5·3.	,,	

Hongo register :—

Duration of the p.t. = 1·8m.

Duraiion of the p.p. = 4·0m.

Total duration = 23m.

P_1, which arrived at 9h 6·7m, was slight, but it was followed by waves increasing their magnitude gradually.

P_3, which arrived at 9h 8·5m, had an amp. of 0.7mm.

P_5, „ 9h 9·4m, „ 0·7mm.

Eqke. No. 246. June 11th 1902 ; 6h 15·3m.

This earthquake originated probably off the coast of Kamchatka at a distance of about 21° from Tokyo, the duration of p.t. given by Omori's H.P. Seismogram having been 5·9m. The times of commencement at, and the epicentral distances from, the different Milne H.P. Stations were as follows :—

Shide	6h	50·3m 47·9 50·2	78.°	Victoria	6h	32·9m,	50.°
				San Fernando	6	52·3,	93.
Kew	6	41·6,	77.	Cape of Good Hope ...	7	20·5,	146.
Bidston ...	6	30·2,	75.	Calcutta	6	35·4,	59.
Edinburgh	6	38·0,	74.	Madras	6	42·1,	71.
Toronto ..	6	52·2,	75.	Batavia	6	13·7,	70.

Most of these observations related to P_3, so that we get 4·6km. per sec. as its transit velocity. (See Fig. 1,c.)

Hongo register :—

Duration of the 1st p.t. = 2·0m.

Duration of the 2nd p.t. = 2·0m.

Duration of the p.p. = 17m.

Total duration = 1h 20m.

P_1, which arrived at 6h 15·3m, had an amp. of 0·1mm.

P_2, „ 6h 17·3m, „ 0·3mm.

P_3, „ 6h 19·3m, „ 1·1mm.

P_5, „ 6h 22·2m, „ 2·5mm.

Assuming the value of V_5, we get $V_3 = 4·2$.

Eqke. No. 246'. June 13th 1902 ; 0h 22·4m.

This earthquake originated off the south-eastern coast of Hokkaido. Observations at the different Meteorological Stations were as follows :—

Tokachi	0h 22·2m.	Strong(r.w.).	
Kushiro 0	21·7.	Weak.	Sharp, houses shaken.
Nemuro 0	21·9.	Slight.	Duration long.
Abashiri 0	22·5.	„	Gentle.
Aomori 0	23·2.	„	Sharp.
Ishinomaki 0	23·5.	„	Accompanied by e.s.
Sapporo 0	24·0.	„	
Wajima 0	24·0.	„	
Miyako 0	24·2.	„	Sharp, accompanied by v.m.
Kumagai 0	22·5.	Slight(unfelt).	
Hakodate 0	23·5.	„	
Mito 0	24·4.	„	
Tokyo 0	25·1.	„	
Yokohama 0	25·2.	„	
Akita 0	25·7.	„	

Hongo register :—

Duration of the p.t. = 1·0m.

Duration of the p.p. = 4·0m.

Total duration = 15m.

P_1, which arrived at 0h 22·4m, was slight.

P_3, „ 0h 23·4m, had an amp. of 0·4mm.

P_5, „ 0h 24·8m, „ 0·6mm.

Eqke. No. 256. July 1st 1902 ; 8h 18·5m.

This earthquake originated off the coast of N.E. Japan. Observations at the different Meteorological Stations were as follows :—

Aomori 8h	16·8m.	Weak(r.s.)	Sharp.
Ishinomaki ...8	17·5.	„	Houses shaken.

Miyako	8h 15·4m.	Slight.
Akita	...8 17·0.	„
Wajima	8 17·9.	„
Yamagata ..	...8 18·3.	Slight(unfelt).
Mito	.. 8 18·5.	„
Tokyo ...	...8 18·5.	„
Kumagai ...	...8 18·8.	„
Yokohama ...	.. 8 19·2.	„

The phase P_5 was observed at Shide at 9h 2·0m, and at Bidston at 9h 0·2m. The epicentral distances of these two stations being 82°, we get 3·4 km. per sec. as the transit velocity of this phase.

Hongo register :—

Duration of the p.t. = 1·0m.

Duration of the p.p. = 6·0m.

Total duration = 20m.

P_1, which arrived at 8h 18·5m, had an amp. less than 0·1mm.

P_3, „ 8h 19·5m, had an amp. of 1·0mm.

P_5, „ 8h 20·7m, „ 1·0mm.

Eqke. No. 271. Aug. 22nd 1902 ; 2h 9·0m.

This was a great Turkestan earthquake that devastated many towns in Kashgar district ; the epicentre, which was situated at a point *long.* 75°E, *lat.* 39°.5 N., being 5570km. distant from Tokyo. The times of commencement at, and the epicentral distances from the different Milne H.P. Station were as follows :—

Shide	3h 10·9m,			Bombay ...	...3h	5·4m,	20.°
	2 59.8,	53.°		Madras ...	...3	4·8,	26.
Bidston	... 2	56·0,	54.	Batavia ...	...3	9·9,	54.
Edinburgh ...	... 3	9·5,	54.	Baltimore	...3	24·5,	98.
Paisley	... 3	10,	54.	Irkutsk ...	...3	5·4,	23.
Toronto	... 3	25·8,	95.	Perth ...	...3	13·6,	80.
Victoria ...	... 3	16·0,	91.	Christchurch	...3	20 6,	121.
San Fernando	... 3	9·1,	63.	Taschkent	...3	2·2,	4.
Cape of Good Hope	3	14·8,	89.				

Of the above observations these at Toronto and Baltimore related probably to P_2, while the remaining ones, excepting that at Paisley and the second entry of Shide observations related to P_1. The graphic representation of the relation between the times of arrival and the epicentral distances, gives 3h 1·6m as the time of commencement at the origin, and 12·7 and 7·3 km per sec. as the transit velocities of P_1 and P_2 respectively. (See Fig. 1,c.)

Hongo register (Fig. 5):—

Duration of the 1st p.t. = 6·4m.
Duration of the 2nd p.t. = 9·0m.
Duration of the p.p. = 40m.
Total duration = 3h 0m.
P_1, which arrived at 3h 9·0m, was slight.
P_2, „ 3h 15·4m, had an amp. of 0·5mm.
P_3, „ 3h 24·4m, „ 0·7mm.
P_5, „ 3h 31·5m, „ 7·0mm.
P_6, „ 3h 37·5m, „ 11·0mm.
P_7, „ 3h 42·4m, „ 10·0mm.
P_8, „ 3h 47·0m, „ 8·0mm.

P_5', which corresponds to the 5th phase propagated along the major arc of the great circle was slightly marked at 5h 55·5m. These observations give the following values of the transit velocities of the different phases:—

$$V_1=12\cdot5,\ V_2=6\cdot7,\ V_3=4\cdot1,\ V_5=3\cdot10,$$
$$V_6=2\cdot59,\ V_7=2\cdot27,\ V_8=2\cdot04,\ \text{and}\ V_5'=3\cdot29.$$

Eqke. No. 275. Sept. 22nd 1902; 1h 51·3m.

This was a large Guam earthquake, which originated at a distance of 2700km. from Tokyo. The epicentral distance from Manila being also 2700km, the earthquake was registered there at 1h 51·4m. The times of commencement at, and the epicentral distances from, the different Milne H.P. Stations were as follows:—

Shide ...	...	2h	6·5m, 5·4,	109.°	Cape of Good Hope	2h	6·3m,	128.°
Kew ...	...	2	5·3,	108.	Calcutta	...1	55·8,	54.
Bidston	...	1	59·6,	108.	Bombay	..1	57·7,	69.
Edinburgh		2	2·0,	107.	Madras	...1	57·5,	62.
Paisley	...	2	5·2,	108.	Batavia	...1	55·3,	42.
Toronto	...	2	6·4,	110.	Trinidad	...2	4(?),	149.
Victoria	...	1	58·5,	81.	Irkutsk	...1	55·0,	51.
San Fernando		2	5·2,	125.	Perth	...1	57·7,	52,
Cairo ...	...	2	4·0,	103.	Christchurch ...	...1	57·3,	61.

By the graphical method (Fig. 1,c), we get 1h 48·1m as the time of commencement at the origin, and 12·1 km. per sec. as the transit velocity of P_1.

Hongo register :—

Duration of the 1st p.t. = 3·0m.

Duration of the 2nd p t. = 3·0m.

Total duration = 2h 20m.

P_1, which arrived at 1h 51·3m, had an amp. of 1·5mm. Here we have a good example in which the 1st p.t. began quite suddenly.

P_2, which arrived at 1h 54·3m, had an amp. of 3·0mm.

P_3, ,, 1h 57·3m, ,, 15·0mm.

P_5, ,, 2h 0·8m, had an amp. not less than 15·0mm.

P_6 could not be distinguished.

P_7, which arrived at 2h 4·9m, had an amp. not less than 15·0mm.

P_8, which arrived at 2h 9·3m, had an amp. not less than 15·0mm.

From these data, we get

$V_1 = 14{\cdot}0$, $V_2 = 7{\cdot}3$, $V_3 = 4{\cdot}9$, $V_5 = 3{\cdot}54$, $V_7 = 2{\cdot}68$, and $V_8 = 2{\cdot}12$.

Eqke. No. 276. Sept. 23rd 1902; 20h 38·6m.

This was a Guatemala earthquake. The times of commencement at, and the epicentral distances from, the different Milne H.P. Stations were as follows :—

Shide ...	...20h	30·9m,	79.°	Cape of Good Hope	20h	38·7m,	114.°
Kew ...	.. 20	31·2,	80.	Calcutta	...20	39·5,	143.
Bidston	...20	27·5,	77.	Madras	...20	39·0,	150.
Edinburgh	.. 20	31·5,	77.	Batavia	...21	10·7,	160.
Paisley	.. 20	30·5,	77.	Trinidad	...20	24·0,	30.
Toronto	...20	24·2,	31.	Irkutsk	...20	34·1,	113.
Victoria	..20	26·0,	43.	Perth	...20	40·1,	150.
San Fernando	19(?)	33·7,	77.	Christchurch ...	...20	44·7,	104.
Cairo ...	...20	32·0,	110.				

These observations, except that at Batavia, related to P_1, so that we get 20h 20·0m as the time of commencement at the origin and 13·3 km. per sec. as the transit velocity of P_1. (See Fig. 1,c.)

The diagram given by Omori's H.P. Seismograph (Fig.6) indicates that the p.t. was chiefly composed of waves of about 15 sec. period, and that in approaching the p.p., the period became larger and larger until at last it reached the maximum of 50 sec. in P_3. Even after P_5, the waves had in general a period greater then 30 sec., so that in the seismogram of our Milne H.P. instrument, for which the period of free oscillation of the pendulum boom was 15 sec., the p.t. ought to be more conspicuously marked than the p.p.

Hongo register (Fig. 5) :—

Duration of the 1st p.t. = 13·7m.

Duration of the 2nd p.t. = 11·7m.

Total duration = 1h 20m.

P_1, which arrived at 20h 38·6m, had an amp. of 0·3mm. At 20h 45·5m and 20h 47·8m, two large waves of amp. of 1·5mm. and 2·7mm. respectively were registered.

P_2, which arrived at 20h 52·3m, had an amp. of 0·6mm. It was closely followed by a d.m. of an amp. of 2·2mm.

P_3, which arrived at 21h 4·0m, had an amp. of 0·7mm.

Other phases were not distinguishable.

From the above observations, we get

$$V_1 = 10{\cdot}8,\ V_2 = 6{\cdot}3, \text{ and } V_3 = 4{\cdot}6.$$

Eqke. No. 286. Nov. 15th 1902; 9h 32·5m.

This earthquake originated probably near Manila. Observations at the different Milne H.P. Stations were as follows:—

Bidston	...	10h	29·4m,	95°	Toronto ...	...	10h	12·0m, 123.°
Victoria	...	9	58·7,	97.	Cape of Good Hope		10	6·0, 108.
Madras	...	9	49·8,		Batavia ...	...	9	28·1, 24.
		10	10·2,	38				
Irkutsk	...	9	28·9,	43.	Perth ...	...	9	34·8, 44.

In Manila, the earthquake was registered at 9h 21·2m. Most of the above observations related to P_3, so that we get 4·5 km. per sec. as its transit velocity. (See Fig. 1,c.)

Hongo register:—

Total duration = 30m.

P_3, which arrived at 9h 32·5m, had an amp. of 0·2mm.

P_5, ,, 9h 37·0m, ,, 1·1mm.

P_6, ,, 9h 39·2m, ,, 1·0mm.

P_7, ,, 9h 42·6m, ,, 0·6mm.

Assuming the values of V_5 and the epicentral distance, we get

$$V_3 = 5·3,\ V_6 = 2·83,\ \text{and}\ V_7 = 2·33.$$

Eqke. No. 288. Nov. 20th 1902; 20h 36·8m.

This earthquake originated probably in the southern Pacific near the Fiji Islands at a distance of 64° from Tokyo. The times of commencement at, and the epicentral distances from, the different Milne H.P. Stations were as follows:—

Shide	...	...	21h	1·3m, 144.°	Bombay	..	20h	45·0m, 111.°
Kew	...	...	21	9·5, 143.	Madras	...	20	50·9, 102.
Bidston	...	...	20	48·4, 143.	Batavia	...	20	37·6, 71.
Edinburgh	...	...	21	4·5, 142.	Baltimore	...	20	48·5, 111.
Toronto	...	...	20	48·1, 109.	Trinidad	...	20	56, 124.
Victoria	...	...	20	40·2, 82.	Irkutsk	...	20	38·8, 93.
San Fernando		...	20	45·2, 160.	Perth	...	20	36·8, 60.
Cape of Good Hope			20	54·2, 126.	Christchurch		20	31·8, 98.
Calcutta	...	...	20	40·6, 99.				

Most of the observations at nearer stations having related to P_1, we get 13·0 km. per sec. as its transit velocity. (See Fig. 1,c.)

Hongo register :—

Duration of the 1st p.t. = 10m.
Duration of the 2nd p.t. = 9·8m.
Total duration = 1h 10m.
P_1, which arrived at 20h 36·8m, was very slight.
P_2, ,, 20h 46·8m, had an amp. of 0·6m.

The maximum wave, whose amp. was 1·2mm., was registered at 20h 47·8m.

P_3, which arrived at 20h 56·6m, was slightly marked.
P_5, ,, 21h 3·8m, had an amp. of 0·7mm.

Other phases were not distinctly marked, on account of the fact that they had too large periods and were not properly registered by our instrument.

Eqke. No. 289. Nov. 21st 1902 ; 7h 8·1m.

This earthquake originated off the southern coast of Formosa, at a distance of 23° from Tokyo. In Manila, the initial earth movement was registered at 7h 1·8m. Observations at the different Meteorological Stations were as follows :—

Taito	7h 12·0m.	Strong.	Houses shaken.
Tainan	7 4·2.	Strong(r.w.).	Accompanied by v.m., houses shaken.
Koshun	7 6·7.	,,	Clocks stopped.
Taichu	7 2·8.	Weak.	Houses shaken.
Taihoku	7 3·0.	Slight.	Duration long.
Ishigakijima ...	7 7·3.	,,	Sharp.
Wajima	7 8·0.(?)	Slight(unfelt).	
Akita	7 9·4.	,,	

The times of commencement at, and the epicentral distances from, the different Milne H.P. Stations were as follows :—

Shide	7h 30·0m, 7 29·0,	94.°	Victoria	7h	26·7m,	93.°
Kew	7	28·2,	92.	San Fernando	7	55·5,	105.
Bidston	7	26·5,	93.	Cape of Good Hope	7	29·5,	110.
Edinburgh	7	23·5,	92.	Calcutta	7	27·7,	30.
Paisley	7	50(?),	93.	Bombay	7	11·5,	44.
Toronto	7	32·7(?),	109.	Madras	7	10·0,	39.
Batavia	7	7·5,	30.	Perth	7	20·7,	52.
Baltimore	7	30·0,	122.	Christchurch	7	23·6,	77.
Irkutsk	7	11·3,	36.				

These observations, except those at Paisley, San Fernando, and Calcutta, related to P_2, so that we get 7h 1·0m as the time of commencement at the origin and 7·4 km. per sec. as the transit velocity of P_2. (See Fig. 1,c.)

Hongo register :—

Total duration = 1h 20m.

P_2, which arrived at 7h 8·1m, had an amp. of 0·6mm.

P_3, ,, 7h 11·1m, ,, 0·4mm.

P_5, ,, 7h 13·9m, ,, 1·2mm.

P_6 was not clearly marked.

P_7, which arrived at 7h 17·7m, had an amp. of 1·6mm.

P_8, ,, 7h 21·3m, ,, 1·8mm.

Besides these different phases, two d.m. were recorded, one at 7h 19·0m and of an amp. of 3·0mm., and the other at 7h 23·0m and of an amp. of 4·0mm.

From the above observations (Fig. 1,c), we get

$V_2 = 6·0$, $V_3 = 4·2$, $V_5 = 3·30$, $V_7 = 2·55$, and $V_8 = 2·10$.

Eqke. No. 295. Dec. 13th 1902 ; 17h 18·3m.

This earthquake occurred probably in India at a distance of about 45° from Tokyo. Observations at the different Milne H.P. Stations were as follows :—

Shide	17h 27·2m.	Calcutta	17h 7·6m.
Kew	17 38·3.	Bombay	17 11·8.

Edinburgh	17	28·0.	Madras	17	11·7.
Toronto	18	18·5.	Batavia	17	15·4.
Victoria	18	0·5.	Irkutsk	17	14·3.
San Fernando ...	17	45·7.	Perth	17	26·5.
Cairo	17	36·0.	Taschkent	17	12·0.

Hongo register :—

Duration of the 2nd pt. = 4·3m.

Total duration = 40m.

P_2, which arrived at 17h 18·3m, had an amp. of 0·1mm.

P_3, „ 17h 22·6m, „ 0·3mm.

P_5, „ 17h 27·9m, „ 0·5mm.

P_6, „ 17h 31·7m, „ 0·8mm.

P_7, „ 17h 35·6m, „ 1·5mm.

P_8, „ 17h 37·6m, „ 0·9mm.

A d.m. of an amp. of 1·4mm. was recorded at 17h 39·3m.

Assuming the values of V_5 and the epicentral distance, we get $V_3=4·2$, $V_6=2·86$, $V_7=2·53$, and $V_8=2·37$.

Eqke. No. 296. Dec. 16th 1602; 5h 22·9m.

This was a large Turkestan earthquake which destroyed Andijan and many towns and villages around it. The epicentral distance from Tokyo was 52°·5. The times of commencement at, and the epicentral distances from, the different Milne H.P. Stations were as follows :—

Shide	5h 24·5m, 5 25·7,	50.°	Calcutta	5h 23·9m,	22.°
Kew	5	25·8,	50.	Bombay 5	12·9,	21.
Bidston	4	55·2,	51.	Madras 5	18·8,	28.
Edinburgh ...	5	22·0,	51.	Baltimore	6	11·6,	100.
Toronto	6	2·9,	97.	Batavia	5	34·9,	56.
Victoria	6	1·0,	93.	Irkutsk	5	18·5,	25.
San Fernando ...	6	25·7,	60.	Taschkent	6	6·2(?),	3.
Cairo	5	2·0,	37.				

The observations at Shide, Kew, Edinburgh, San Fernando, Cairo, Madras, Irkutsk, and Taschkent, which related to P_1, gives 5h 15·2m as the time of occurrence at the origin and 13·3 km. per sec. as the transit velocity of P_1. (See Fig. 1,c.)

Hongo register:—

Duration of the p.t. = 15·6m.

Total duration = 1h 10m.

P_1, which arrived at 5h 22·9m, could only be perceived after a comparative study of the seismograms given by Milne's and Omori's H.P. seismographs. P.o. which interfered the whole earthquake motion, also masked P_2 in the photogram.

P_3, which arrived at 5h 38·5m, had an amp. of 0·4mm.

P_5, ,, 5h 42·5m, ,, 0·4mm.

From these observations (Fig. 1,c), we get

$$V_1 = 12{\cdot}5,\ V_3 = 4{\cdot}1, \text{ and } V_5 = 3{\cdot}5.$$

Eqke. No. 298. Dec. 28th 1902; 1h 50·2m.

This was an Altai earthquake. The epicentral distance from Tokyo was 40.° The times of commencement at, and the epicentral distances from, the different Milne H.P. Stations were as follows:—

Kew	2h	5·8m,	54.°	Bombay	1h	58·8m,	31.°
Bidston	2	59,	54.	Madras	2	1·0,	34.
Edinburgh	2	9·0,	53.	Batavia	2	14·6,	55.
Toronto	2	38·4,	88.	Irkutsk	1	46·2,	11.
San Fernando	2	12·0,	67.	Taschkent	1	47·4,	15.

Observations at the two nearer stations related to P_1, and the others to P_3, so that we get 1h 44·8m as the time of commencement at the origin, and 4·2km. per sec. as the transit velocity of P_3.

Hongo register:—

Duration of the 1st p.t. = 6·0m.

Duration of the 2nd p.t. = 5·6m.

Total duration = 30m.

P_1, which arrived at 1h 50·2m, had an amp. of 0·1mm. The whole earthquake motion having been obscured more or less by the slow p.o., P_1 was not clearly defined.

P_2, which arrived at 1h 56·2m, had an amp. of 0·1mm.

P_3, ,, 2h 1·8m, ,, 0·3mm.

P_5, ,, 2h 6·5m, ,, 1·7mm.

P_7, ,, 2h 13·0m, ,, 0·7mm.

From these observations, we get

$$V_1=13\cdot7,\ V_2=6\cdot5,\ V_3=4\cdot4,\ V_5=3\cdot41,\ \text{and}\ V_7=2\cdot66.$$

IV. Transit velocities of the different phases.

The transit velocities of the different phases of the earthquake motion deduced from the Hongo observations are given in Tables I and II.

Table I relates to earthquakes whose origins were definitely known, and consequently the times of occurrence at origin could be estimated with fair accuracy. The velocities given in this table were obtained, in each case by dividing the arcual epicentral distance by the time interval taken in transit.

Table II relates to earthquakes whose origins were roughly determined by the method of times of arrival or the method of duration of the preliminary tremor. In this case, the transit velocities of the different phases in the principal portion have been estimated by assuming the value of V_5.

TABLE I.

No.	Date.	Origin.	Ep. dist. from Tokyo.	V_1	V_2	V_3	V_5	V_6	V_7	V_8	V'_3	V'_5	V'_6
3	Sept. 4, 1899.	Alasca.	55.0	14.5	7.3	4.2	3.1	—	—	—	—	—	—
7	Sept. 20, 1899.	Smyrna.	83.0	13.3	6.9	4.4	3.26	2.83	2.46	2.20	—	3.25	2.92
8	Sept. 23, 1899.	Alasca.	55	—	7.0	—	—	2.78	—	—	—	—	—
9	Sept. 29, 1899.	Ceram(Java).	43.2	11.0	6.3	4.6	32.8	2.73	2.33	2.08	—	—	—
12	Oct. 19, 1899.	Javan district.	49	12.7	6.7	4.7	3.70	—	—	2.26	—	—	—
29	Jan. 20, 1900.	Mexico.	101	13.2	6.1	4.2	3.04	2.60	2.37	2.12	—	3.22	—
106	Dec. 25, 1900.	Off Kurile Is.	11.4	13.1	—	5.1	3.55	—	—	—	—	—	—
209	Dec. 14, 1901.	Manila.	27.0	11.6	6.9	4.5	3.47	2.77	—	2.23	—	—	—
239	April 19, 1902.	Guatemala.	110.5	15.8	7.5	5.3	3.50	—	2.43	2.12	5.4	—	—
271	Aug. 22, 1902.	Turkestan.	50.0	12.5	6.7	4.1	3.10	2.59	2.27	2.04	—	3.29	—
275	Sept. 22, 1902.	Guam.	24.3	14.0	7.3	4.9	3.54	2.68	—	2.12	—	—	—
276	Sept. 23, 1902.	Guatemala.	110	10.8	6.3	4.6	—	—	—	—	—	—	—
289	Nov. 21, 1902.	Off S. Formosa.	23	—	6.0	4.2	3.30	—	2.55	2.10	—	—	—
296	Dec. 16, 1902.	Andijan.	52.5	12.5	—	4.1	3.50	—	—	—	—	—	—
298	Dec. 28, 1902.	Altai.	40	13.7	6.5	4.4	3.41	2.63	—	—	—	—	—
Average.	—	—	55	13.1	6.8	4.5	3.37	2.71	2.41	2.15	5.4	3.25	2.92

TABLE II.

No.	Date.	Possible origin.	Ep. dist. from Tokyo.	V_3	V_6	V_7	V_8
10	Oct. 4, 1899.	Bonin curve.	8.0	5.4	2.67	—	—
24	Jan. 11, 1900.	Near Guam Is.	30	4.4	2.87	2.40	—
43	March 9, 1900.	Javan district.	50	4.3	2.84	2.51	2.15
52	April 24, 1900.	Off the S. coast of Formosa.	19	4.7	2.76	2.41	2.11
56	June 2, 1900.	Bonin curve.	12	4.7	2.73	—	2.18
69	Sept. 24, 1900.	Off the coast of Mutsu.	5.4	4.7	—	—	1.99
71	Oct. 7, 1900.	Philippins.	31.5	4.7	2.77	2.45	2.04
73	Oct. 9, 1900.	Alasca.	47	4.4	2.79	2.48	2.16
77	Oct. 18, 1900.	Near Batavia.	36	4.4	2.87	—	—
88	Nov. 12, 1900.	W. Pacific.	42	4.2	3.02	—	2.15
99	Nov. 24, 1900.	Off the coast of Nemuro.	13	4.7	—	2.42	2.17
117	Feb. 15, 1901.	Off the W. coast of Sumatra.	45	4.1	2.88	2.53	—
119	Feb. 20, 1901.	Near Philippines.	25	4.3	—	—	—
132	May 14, 1901.	Off the coast of Nemuro.	8	4.4	—	—	1.93
189	Aug. 10, 1901.	Philippines.	30	3.9	—	—	2.27
200	Oct. 19, 1901.	Do.	28	4.4	—	—	2.30
227	March 1, 1902.	Off the N. coast of Formosa.	18.5	4.0	—	—	—
238	April 11, 1902.	Bonin curve.	17	4.9	2.75	2.36	2.07
243	May 8, 1902.	Off the coast of S.E. Kūshū.	11	4.6	—	—	—
246	June 11, 1902.	Off the coast of Kamchatka.	21	4.2	—	—	—
286	Nov. 15, 1902.	Near Manila.	27	5.3	2.83	2.33	—
295	Dec. 13, 1902.	India.	45	4.2	2.86	2.53	2.37
Average.	—	—	26	4.5	2.82	2.44	2.15

The transit velocities of the different phases deduced from the observations at the different Milne H.P. Stations are given in Tables III and IV.

Table III relates to Japan earthquakes which were instrumentally observed at some of the different Japanese Meteorological Stations.

Table IV relates to earthquakes which originated out of Japan.

TABLE III.

No.	Date.	Origin.	V_1	V_2	V_3	V_5
28	Jan. 18, 1900.	Off the S. coast of Hokkaido.	—	6.3	—	—
44	March 12, 1900.	Off the coast of N.E. Japan.	—	6.9	—	—
52	April 24, 1900.	Off the S. coast of Formosa.	12.5	—	—	—
52′	May 11, 1900.	Off the coast of N.E. Japan.	12.2	6.7	—	—
66	Aug. 5, 1900.	Do.	—	6.0	—	3.45
87	Nov. 9, 1900.	Near Izu Is.	—	—	4.4	3.56
91	Nov. 14, 1900.	N.E. Japan.	—	6.6	—	3.30
99	Nov. 24, 1900.	Off the coast of Nemuro.	12.9	7.4	—	—
103	Dec. 7, 1900.	Near Noto.	—	—	4.0	—
106	Dec. 25, 1900.	Off Kurile Is.	14.7	—	—	—
127	April 5, 1901.	Off the coast of Hokkaido.	12.8	7.2	—	3.19
132	May 14, 1901.	Off the coast of Nemuro.	—	7.4	—	—
187	Aug. 9, 1901.	Mutsu.	12.7	—	—	—
188	Do.	do.	11.0	—	—	—
217′	Jan. 30, 1902.	Off the coast of Hokkaido.	11.7	6.7	—	—
217″	Jan. 31, 1902.	Do.	13.0	6.7	—	—
227	March 1, 1902.	Off the N. coast of Formosa.	—	—	4.2	—
238	April 11, 1902.	Bonin curve.	—	7.7	—	—
242	May 2, 1902.	Off the coast of N.E. Japan.	—	6.4	—	—
243	May 8, 1902.	Off the coast of S.E. Kūshū.	—	—	4.1	—
256	July 1, 1902.	Off the coast of N.E. Japan.	—	—	—	3.40
389	Nov. 21, 1902.	Off the coast of S. Formosa.	—	7.4	—	—
Average.	—	—	12.6	6.9	4.2	3.38

TABLE IV.

No.	Date.	Origin.	V_1	V_2	V_3	V_5
3	Sept. 4, 1899.	Alasca.	12.9	—	—	—
7	Sept. 20, 1899.	Smyrna.	13.5	6.9	—	—
8	Sept. 23, 1899.	Alasca.	13.8	6.7	—	—
9	Sept. 29, 1899.	Ceram(Java).	12.0	—	—	—
12	Oct. 19, 1899.	Javan district.	12.3	—	—	—
24	Jan. 11, 1900.	Near Guam Is.	13.3	—	—	—
29	Jan. 20, 1900.	Mexico.	14.5	—	—	—
34	Feb. 3, 1900.	Near Batavia.	—	—	—	3.45
43	March 9, 1900.	Javan district.	12.9	—	—	—
71	Oct. 7, 1900.	Philippines.	12.7	—	—	—
73	Oct. 9, 1900.	Alasca.	13.7	—	—	—
77′	Oct. 29, 1900.	Caracas.	14.5	—	—	—
79	Nov. 5, 1900.	Izu Islands.	—	6.2	—	—
88	Nov. 12, 1900.	Javan district.	13.3	—	—	—
119	Feb. 20, 1901.	Near Philippines.	—	7.1	—	—
125	March 23, 1901.	Off the coast of Kamchatka.	12.5	6.6	4.3	—
189	Aug. 10, 1901.	Philippines.	12.0	5.2	4.7	—
191	Aug. 11, 1901.	Marianne.	—	—	5.1	—
209	Dec. 14, 1901.	Manila.	13.6	—	—	—
239	April 19, 1902.	Guatemala.	15.6	7.6	4.6	3.18
246	June 11, 1902.	Kamchatka.	—	—	4.6	—
271	Aug. 22, 1902.	Turkestan.	12.7	7.3	—	—
275	Sept. 22, 1902.	Guam.	12.1	—	—	—
276	Sept. 23, 1902.	Guatemala.	13.3	—	—	—
286	Nov. 15, 1902.	Near Manila.	—	—	4.5	—
288	Nov. 20, 1902.	Near New Zealand.	13.0	—	—	—
296	Dec. 16, 1902.	Audijan.	13.3	—	—	—
298	Dec. 28, 1902.	Altai.	—	—	4.2	—
Average.	—	—	13.4	6.7	4.6	3.31

The result of observations contained in Table I is represented in Fig. 3, which shows the relation between the epicentral distances and the time intervals taken in transit by the phases P_1, P_2, P_3, and P_5 respectively. In every case it will be seen that the relation is approximately linear. From the mean curves, which are practically straight lines, we get

$$V_1=13{\cdot}5,\ V_2=6{\cdot}7,\ V_3=4{\cdot}5,\ \text{and}\ V_5=3{\cdot}33.$$

Fig. 4 represents similar relation deduced from the observations to which Tables III-IV relate. The curve for P_1, whose observations were distinguished from P_2's in each earthquake as explained in p.19, is also fairly linear and gives 13·2 km. per sec. as the value of the transit velocity. As regards the observations of P_2, some might possibly have related to other phases, so that the curve for it does not fairly represent the liuear relation as in the two other cases (Figs. 2-3), the 1st of which relates to the result of my own deduction of the illustration of seismograms given in Milne's Circulars, No. 6.

V. Alasca earthquake of Jan. 1, and Guatemala earthquake of April 19, 1902.

No. 6 of Prof. Milne's Circulars contains amongst others many important illustrations of seismcgrams which were obtained at the different Milne H.P. Stations. I give next the result of an examination of some of these illustrations which relate, firstly, to the Alasca earthquake of Jan. 1, and secondly, to the Guatemala earthquake of April 19, 1902.

The Alasca earthquake of Jan. 1, 1902. As I had no other information about the origin of this earthquake than the remark given by Mr. Reid of Victoria, that it occurred in Alasca, I have determined the approximate position of origin by the method of duration of the preliminary tremor. As regards the seismogram obtained at

Victoria, the three waves which arrived at 5h 26·5m, 5h 32·0m, and 5h 34·0m may be assumed to be P_1, P_2, and P_3 respectively, so that the duration of the preliminary tremor was about 7·5m. In Japan, Omori's instrument at Hongo registered P_1 at 5h 27·3m as a minute tremor which was followed by waves gradually increasing in magnitude, P_2 at 5h 32·8m (amplitude=0·03mm), and P_3 at 5h 36·0m (amplitude=0·07mm), so that the duration of the preliminary tremor amounted to 8·7m. Thus the epicentre was probably situated near Atcha Island in the Aleutian Archipelago.

In the seismogram obtained at Victoria, diagramatic maxima were registered several times before and after P_5, so that the waves of about 15 sec. period ought to have developed themselves in these stages. Taking this circumstance into account, I have carefully examined the seismograms at the other stations and assumed the waves which arrived at the times given in the following table to be P_1, P_2, P_3, and P_5.

Stations.	Ang. dist.	Times of arrival of			
		P_1	P_2	P_3	P_5
Shide.	77°	5h 32.4m	5h 44.3m	5h 53.4m	6h 3.8m
Kew.	76	—	4 45.7	—	6 6.8
Edinburgh.	73	—	—	6 54.3	6 7.5
Toronto.	59	5 40.0	—	—	5 56.0
Victoria.	33	5 26.5	5 32.0	5 34.5	5 40.0
Cape of Good Hope.	159	—	6 3.0	6 30.0	—
Baltimore.	64	5 32.2	5 40.5	5 50.0	5 59 5
Madras.	88	—	5 43.7	5 55.7	6 8.5
Christchurch.	94	—	5 44.5	5 0.4	—
Tokyo.	37	5 27.3	5 32.8	5 36.0	—

A graphic representation of the relation between the times of arrival

of the different phases and the epicentral distances (Fig. 2,a) gives the following results :—

$$V_1=14{\cdot}4,\ V_2=7{\cdot}1,\ V_3=4{\cdot}8,\ \text{and}\ V_5=3{\cdot}4.$$

The Guatemala earthquake of April, 19, 1902. A detailed account of this great earthquake is given by Mr. Rockstroh[1]. The time of occurrence 20h 25m (April 18th), Guatemala M.T., or 2h 27m (April 19th) in Greenwich M.T., is probably the average value of the times at which the disturbance was personally felt in the different districts of the most disturbed area[2]. From this consideration as well as from the graphic study of the relation between the times of arrival of the different phases and the epicentral distances, it seems more proper to adopt 2h 26m in Greenwich M.T. as the time of commencement of the first preliminary tremor at the seismic focus. The epicentre, which ought to lie within the meizoseismal area, namely, the south-western corner of the Republic, was probably situated rather in the eastern part of that area than at the centre, as the other seismals extended far to the east. Let us assume therefore the position of the epicentre to be at a point *long.* 91°12′W, *lat.* 14°30′N. The arcual epicentral distances from the different stations were calculated according to the formula given in p. 21.

Beside the seismograms obtained at the different stations contained in Prof. Milne's Circulars No. 6, I have taken into consideration that obtained in Tokyo and the result of observation at Calcutta. In each seismogram, I have distinguished the different phases and estimated their times of arrival, the result being as shown in the following table :—

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1. Nature, Nos. 1702 and 1734, Vol. 66.

2. According to Prof. Milne, the time of occurrence in the epicentre was 6h 21–22m Adopting it, the time curve for each phase must be shifted parallel to itself, the ordinate corresponding to each observation being increased by 4–5 min.; yet the *linear* relation between the times taken in transit and the arcual distances does still hold so far as the observations at *distant* stations are concerned.

Milne H.P. Station.	Ep. dist. along minor arc.	Ep. dist. along major arc.	Commencement.	Time taken in transit. P_1	P_2	P_3	P_5	P_6	P'_7	P_8	P'_3	P'_5
Toronto.	30°8		2h 30.5m	4.5	8.9	14.5	17.5	20.0	22.9	27.7	—	—
Victoria.	43.2		31.3	5.3	11.4	18.7	24.5	—	33.6	37.9	—	—
Edinburgh.	77.0		36.0	10.0	19.5	32.4	47.6	53.7	59.9	68.3	—	—
Bidston.	77.2		35.0	9.0	18.8	34.6	48.1	55.5	63.0	72.6	—	—
San Fernando.	77.4		34.8	8.8	17.5	29.7	40.2	51.4	59.3	67.2	—	—
Shide.	78.7		35.4	9.4	19.3	31.7	48.4	56.7	66.2	—	—	—
Kew.	79.4		36.2	10.2	21.0	33.7	47.5	54.3	64.0	74.8	—	—
Wellington.	100.7		38.0	12.0	23.2	44.2	54.5	—	—	89.0	—	—
Christchurch.	103.6	256.4	37.2	11.3	22.5	45.7	51.9	—	74.2	87.0	105.5	—
Tokyo.	110.5	249.8	38.8	12.8	27.0	38.5	58.3	—	83.0	96.8	102.0	—
Cape of Good Hope.	114.0		38.4	12.4	27.4	47.1	62.2	76.0	94.2	106.5	—	—
Bombay.	143.3		43.3	17.3	40.2	61.3	83.7	—	112.0	—	—	—
Calcutta.	143.4		44.0	18.0	—	—	—	—	—	—	—	—
Perth.	150.0	210.0	43.8	17.8	31.3	55.1	84.8	—	—	—	81.0	—
Madras.	150.8		29.0(?)	13.0	36.7	58.7	85.2	99.0	—	—	—	—
Batavia.	160.7	199.3	43.7	17.7	44.2	72.0	93.0	—	—	—	—	121.5(?)

P_3' and P_5' in the last two columns denote respectively the third and the fifth phases of the earthquake motion propagated along the major arc.

The relation between the arcual epicentral distances and the times taken by each phase in its transit is approximately linear. For the preliminary tremors, this relation is more definite in the first phase than in the second. (See Figs. 2, a-b.) The average values of V_1 and V_2 turn out, if we assume them to be propagated parallel to the earth's surface, to be 15·6 and 7·6 km. per sec. respectively.

In the curve for P_3 (Fig. 2,b), I add the data respecting the waves propagated along the major arc of the earth from the origin to the seismic stations such as Perth, Tokyo, and Christchurch. These stations are near the antipode of the origin, and we find that the waves

propagated in the two opposite paths arrived there closely to each other, so that the distinction of the two waves is not definite. If the end portion of the earthquake motion, which is wanting in each illustration of the seismograms, be examined, much interesting result might possibly have been obtained. From Fig. 2,b, it will be seen that the curve is approximately linear and gives 4·6 km. per sec. as the value of V_3.

The 3rd phase of the principal portion, that is, P_5, is one most fully investigated. It is known to be the *longitudinal* wave and to have a transit velocity of 3·3 km. per sec. The value of the transit velocity obtained from our diagram (Fig. 2,b), is equal to 3·2 km. per sec.

Though the number of observations relating to P_6 and P_7 is not sufficient, yet we see from the diagrams (Fig. 2,c) that the values of V_6 and V_7 are about 2·7 and 2·4 km. per sec. respectively.

The 6th phase of the principal portion P_8 is one which is regarded by Prof. Omori to be the *transverse* wave. It develops itself sometimes quite distinctly and is easily distinguished from the preceding stages, as is seen in the seismogram of the Mexico earthquake of Jan. 20, 1900 (Fig. 5). The velocity of transit comes out to be 2·1 km. per sec. (Fig. 2,c), so that the ratio $V_5 : V_8$ is 1·5, a value favorable to the assumption that the waves are transverse.[1]

VI. General Conclusion.

In the present paper, I have confined myself to the observations of earthquakes which occurred during the three and half years from July 1899 to Dec. 1902. Of the 30 large earthquakes, which originated out of Japan, 17 occurred in East Indian district, 5 in Caucasian and Himalayan districts, 4 in the district bordering the Gulf of Mexico, 3 in Alascan district, and one near New Zealand. Of the 19 large

1. See Dr. Omori :—The *Publications*, No. 13, § 47.

earthquakes, which originated in or near Japan, the majority occurred off the Pacific coasts of N.E. Japan, Hokkaido, and the Kurile Island and only a few near Formosa and Kyūshū. Thus we see that most of the large earthquakes were submarine, of the 19 Japan earthquakes only two having been the inland ones. From the observations of these large earthquakes, we get the average transit velocities of the different phases as follows :—

$V_1=13{\cdot}2$, $V_2=6{\cdot}8$, $V_3=4{\cdot}5$, $V_5=3{\cdot}3$, $V_6=2{\cdot}8$, $V_7=2{\cdot}4$, and $V_8=2{\cdot}1$.

These values, which were obtained on the assumption that the paths of the different phases of the earthquake motion are parallel to the earth's surface, do not much differ from those deduced by Dr. Omori from the seismic observations in Europe and Tokyo[1]. My graphic method of deduction, in which the relation between the arcual epicentral distances from *distant* stations and the time intervals taken in transit by the different phases is represented by a straight line, as in eqkes, No. 187 (Fig. 1, b) and No. 239 (Figs. 2, a-b)[2], is similar to his advantageous method of estimating the velocities by dividing the difference of arcual epicentral distances by that of times of arrival, as in the case of the Caracas earthquake of Oct 29, 1900. The deduced values are, however, approximated by those which have been obtained by dividing the epicentral distance from a distant station by the time interval taken in transit.

If we assume the path of P_1 to be along the chord, the time relation is not represented by a straight line as is to be understood from the following table where the data are taken from the observations at the different Milne H.P. Stations of eqkes. Nos. 29, 52, 52′, 99, 127, 187, 188, 209, 217′ 217″, and 271, in which accurate instrumental observations were made in the epicentral districts.

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1. Dr. Omori: The *Publications* Nos. 5 and 13.
2. The reader is referred to the foot note, p. 112.

Table for V_1.

Distance. / V_1 estimated along:	20°	40°	60°	88°	100°	120°	140°
Arc from epicentre.	9·8	10·3	10·9	11·6	12·2	12·3	12·6
Arc from places whose epi. dist = 30°.	—	—	13·7	13·7	13·7	13·7	13·7
Chord from epicentre.	9·7	10·1	10·4	10·7	10·7	10·2	9·7

From the above table also it seems more proper to assume the path for P_1 to be parallel to the earth's surface. That the value of V_1 in cases of near earthquakes is small may probably be explained by assuming Prof. Nagaoka's *stratum giving maximum transit velocity*[1] at a moderate depth (say a few hundred km.) below the earth's surface so that the wave P_1, which starts from a comparatively shallow seismic focus, finds its way directly toward the observing station along a short path in an upper less elastic layer, such that the most elastic stratum forms a little, or no, part of the whole path. Hereby it may be remarked that the Japan earthquake of Aug. 1901 (eqke. No. 187), whose origin was very shallow, had 11·5 km. per sec. as the value of V_1 for the 1st 50°, but 13·8 km. per sec. if it is estimated by dividing the difference of epicentral distances by that of the times of arrival. The difference of the two values may be explained by assuming, as before, the existence of the most elastic stratum ; for the velocity obtained by the 1st method relates not only to that stratum but also to those which lie between the latter and the seismic focus or the observing station, whilst in the 2nd method the terms relating to the less elastic media are cancelled by the process of taking the difference, and the velocity relating only to the most elastic stratum is given.

As regards the paths of the vibrations in the other phases, we arrive at the similar conclusion, the time curve in each case being approximately linear. For the medium through which P_2 is propagated, we have a reason to consider it to be rather superficial as the transit velocity such

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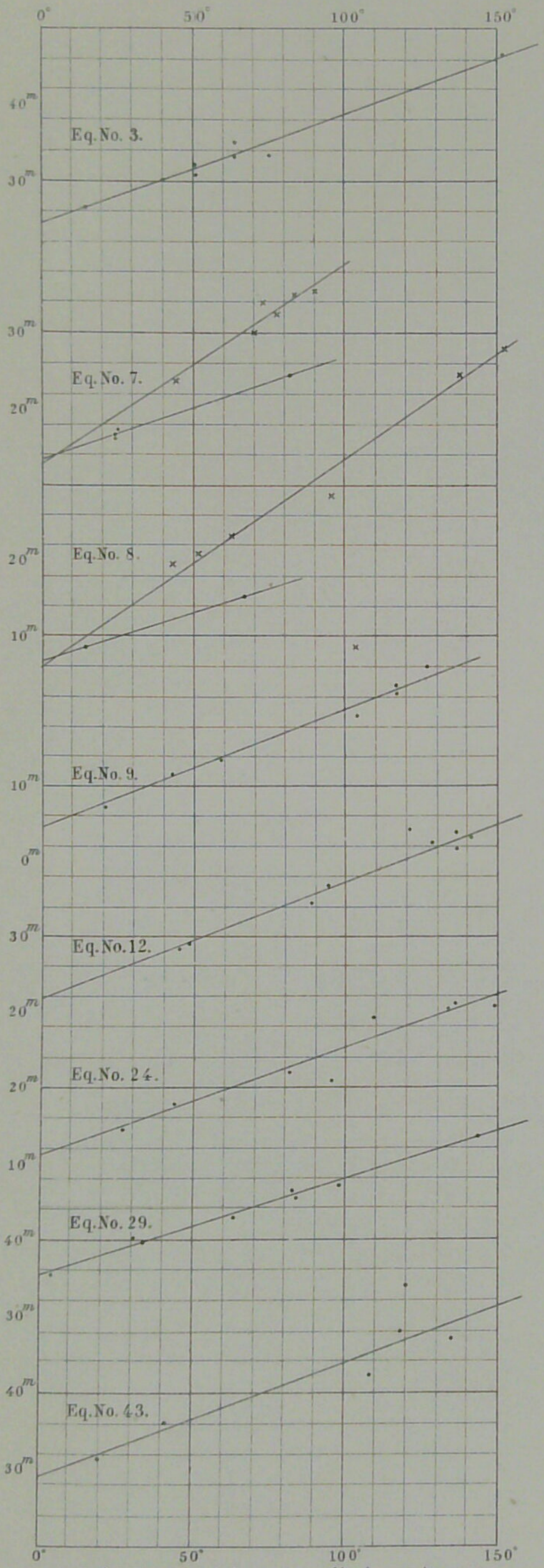
1-2. Prof. Nagaoka : *Elastic constants of rocks.* The *Publications*, No. 4.

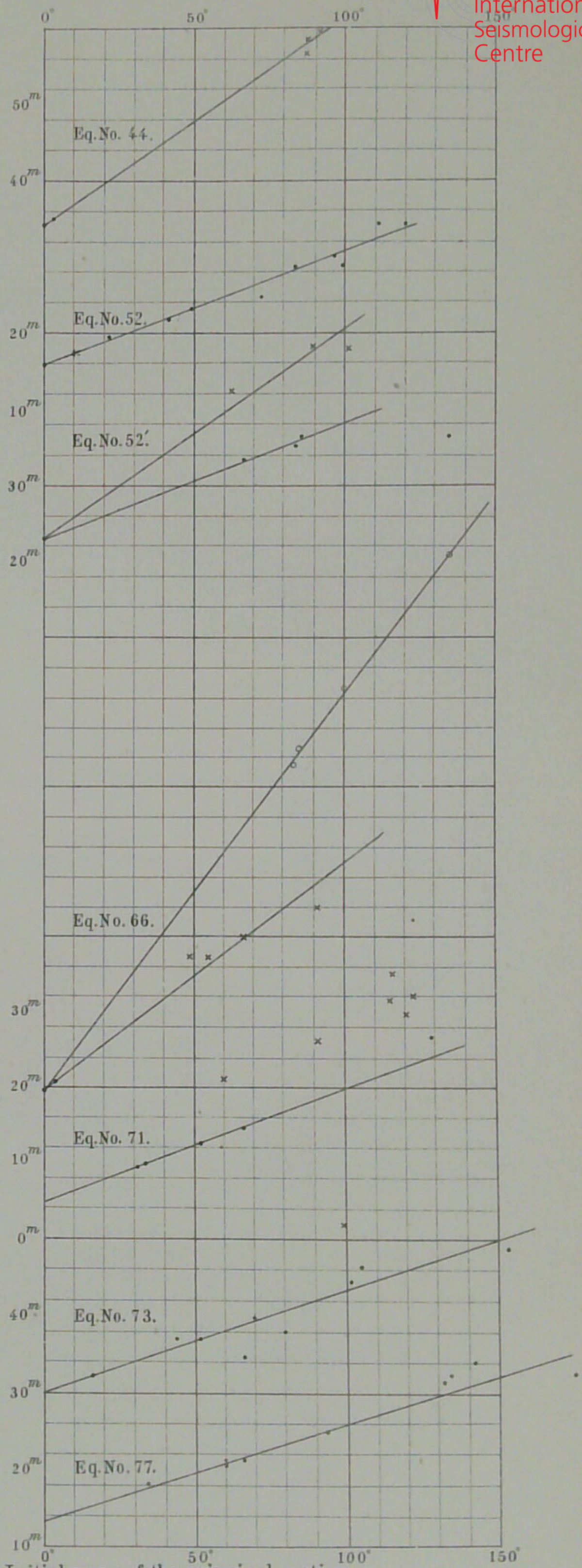
as 6-7 km. per sec. is found even in cases of near earthquakes. It may possibly be a stratum of primeval formation, for, according to Prof. Nagaoka, the velocity in the archean rocks ranges from 6 to 7 km. per sec.

Besides the different phases hitherto mentioned, there may possibly exist waves transmitted through the earth's interior at great depth below the surface. Allowing the existence of the most elastic stratum, the waves propagated from the upper one toward it with an incident angle of about 90° will pass through it, while those which strike it with a small incident angle are totally refracted. The waves which can penetrate the stratum will converge after they pass through it, and will be directly transmitted within comparatively narrow area around the antipode. I can not, however, distinguish such waves in the seismograms at my disposal, so that the investigation must be reserved for a future occasion when a large earthquake originating near our antipode would have been registered in Tokyo.

Jan. 1904. Seismological Institute, Tokyo.

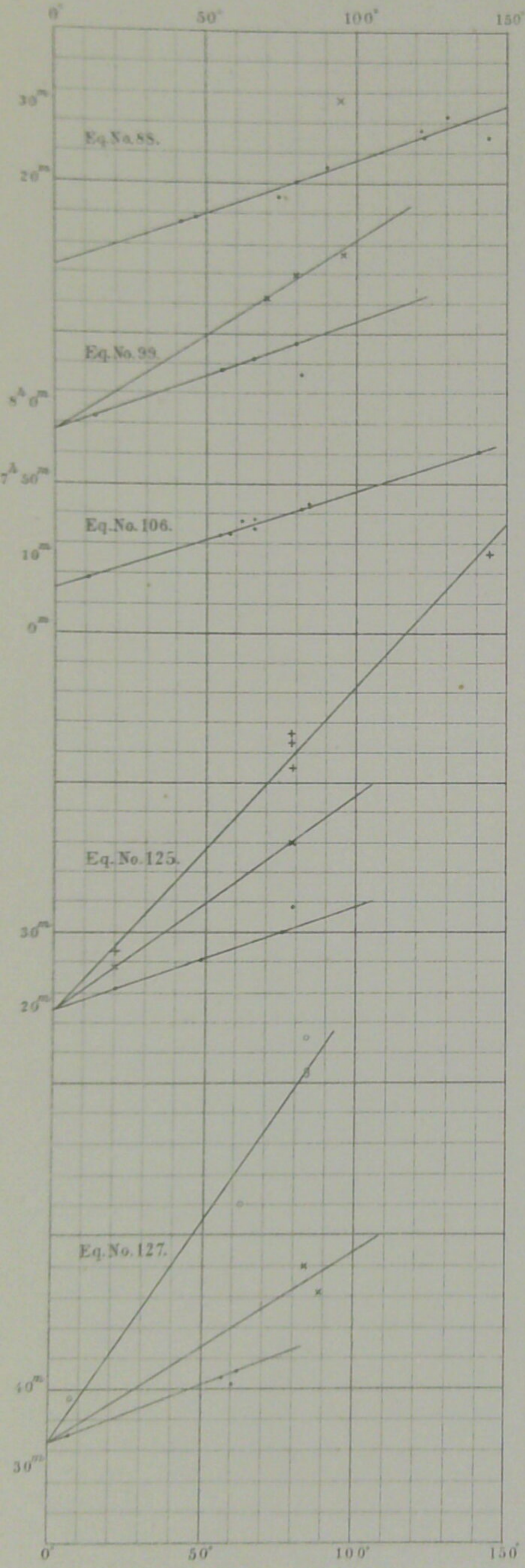
Fig. 1, a.





● ... Initial wave of the 1st preliminary tremor.
× .... „ 2nd „ .
+ .... Initial wave of the principal portion.
○ .... „ most active part of principal portion.

Fig. 1, b.


0°
50°
100°
150°
30m
Eq.No.88.
20m
Eq.No. 39.
8h 0m
7h 50m
Eq.No. 106.
10m
0m
Eq.No. 125.
30m
20m
Eq.No. 127.
40m
30m
0°
50°
100°
150°

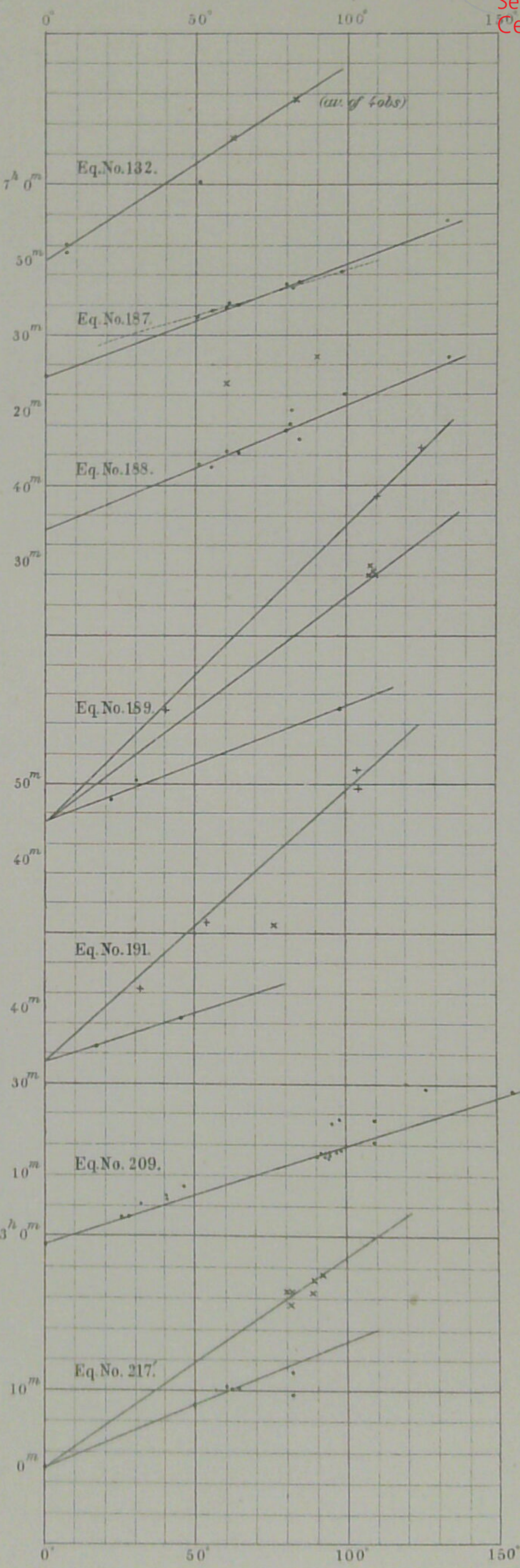
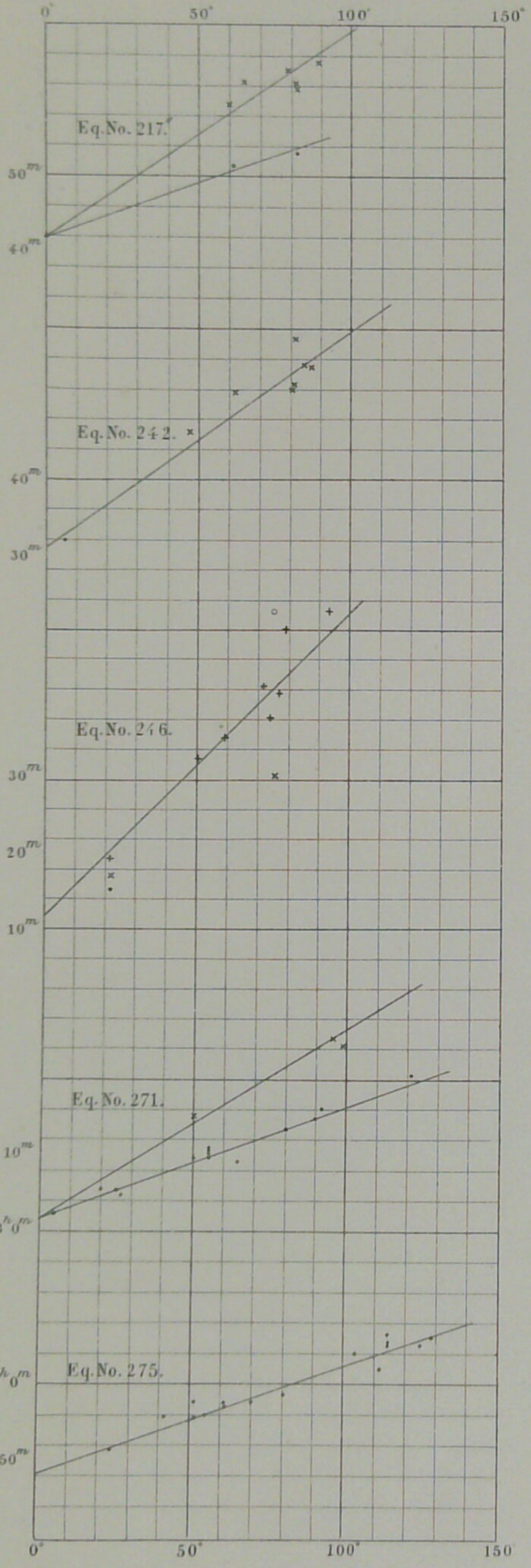

0°
50°
100°
150°
(av. of 4obs)
Eq.No.132.
7h 0m
50m
Eq.No.187.
30m
20m
Eq.No.188.
40m
30m
Eq.No.189.
50m
40m
Eq.No.191.
40m
30m
Eq.No. 209.
10m
2h 0m
Eq.No. 217.
10m
0m
0°
50°
100°
150°

Fig. 1, c.



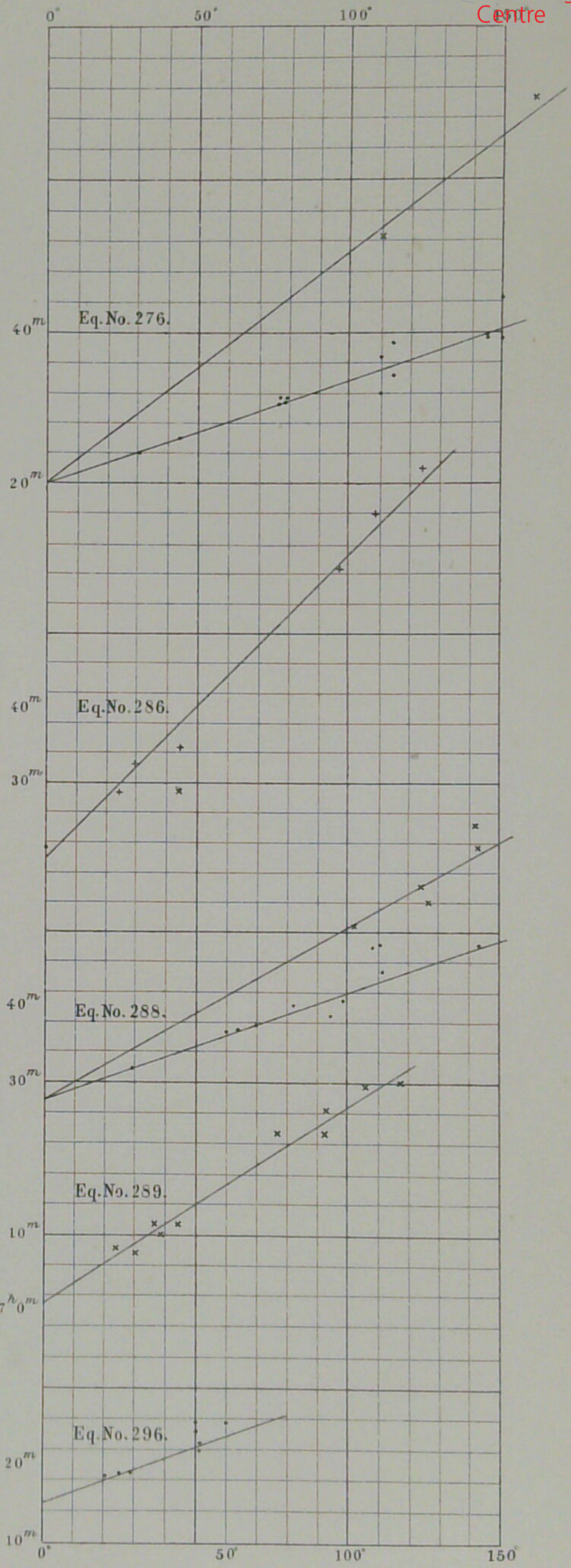
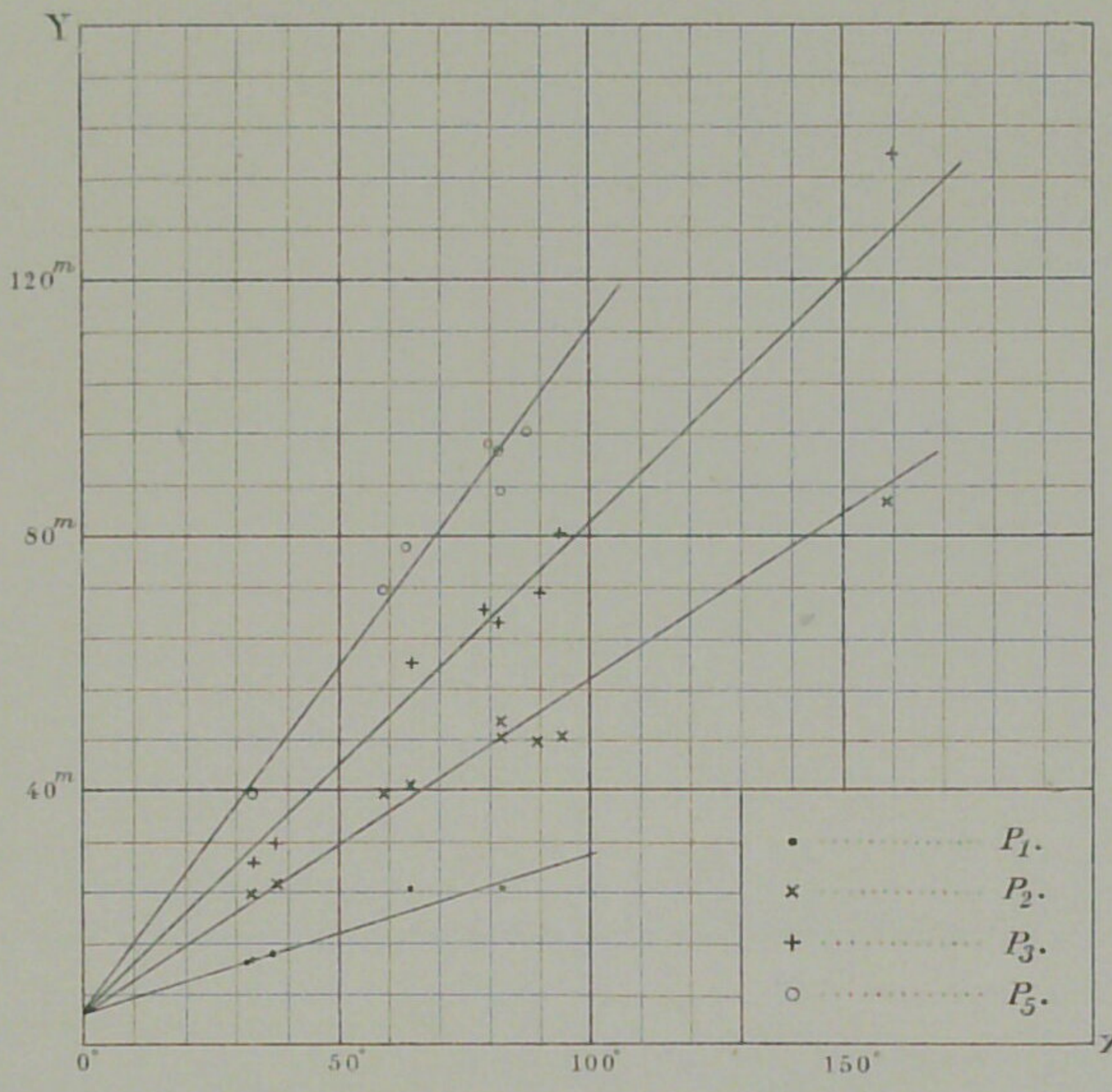


Fig. 2, a.

Alasca earthquake:



Guatemala earthquake:

Curve for P_1.

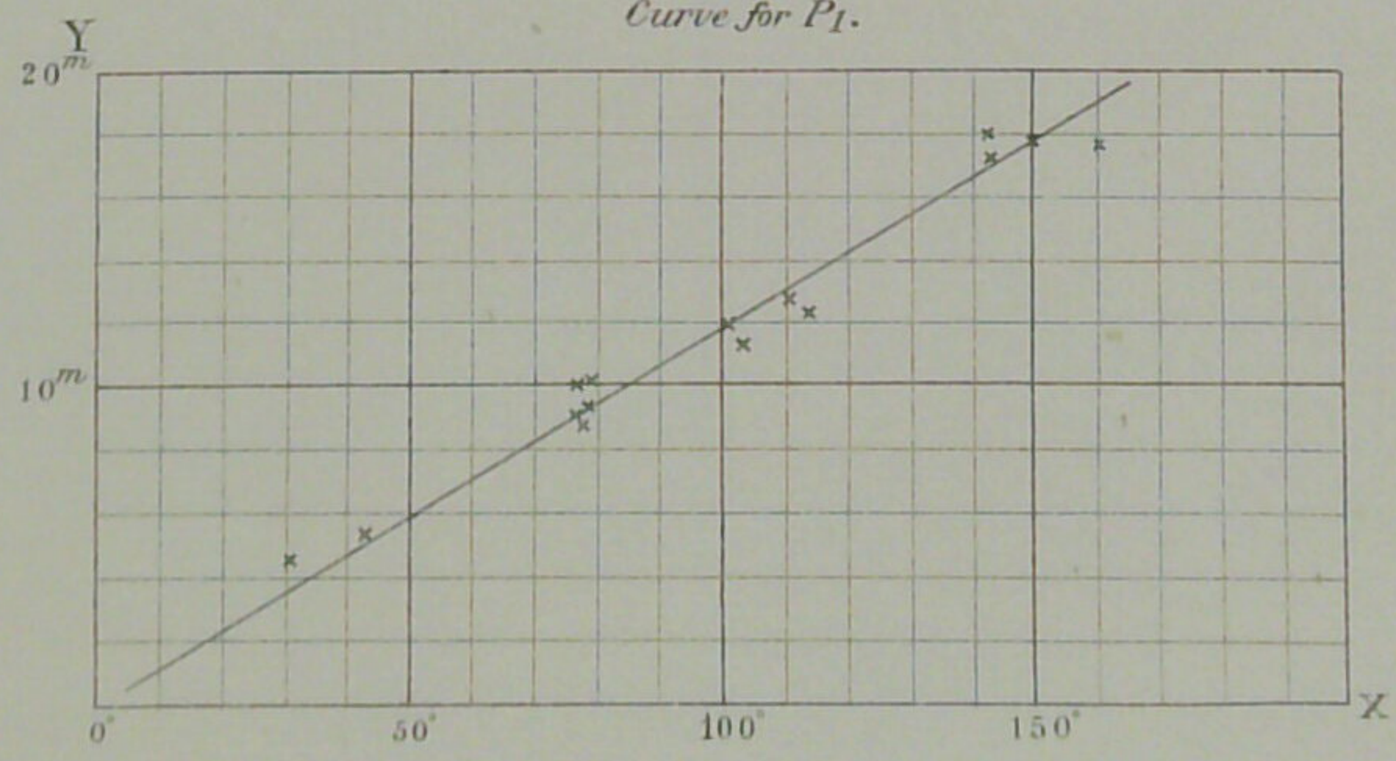
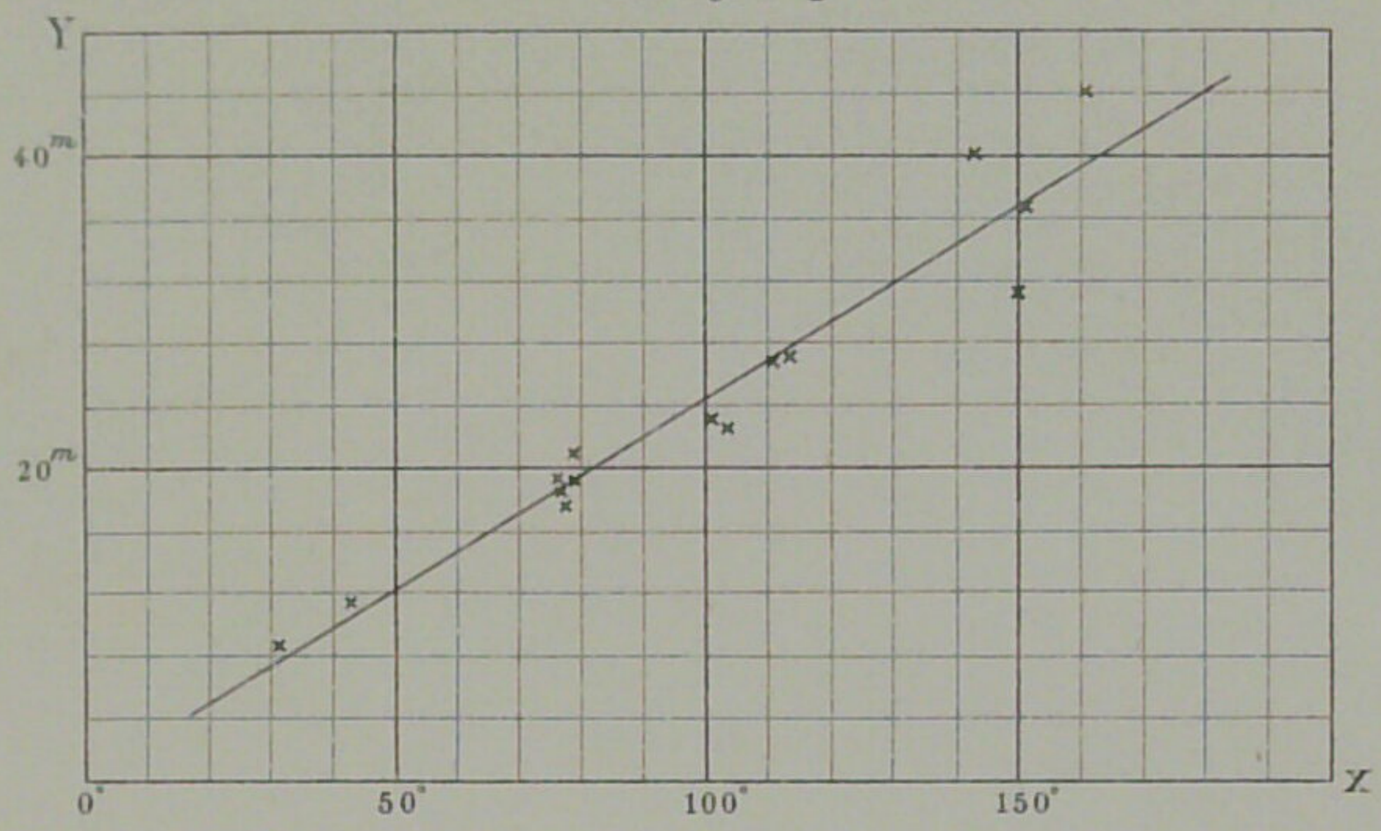


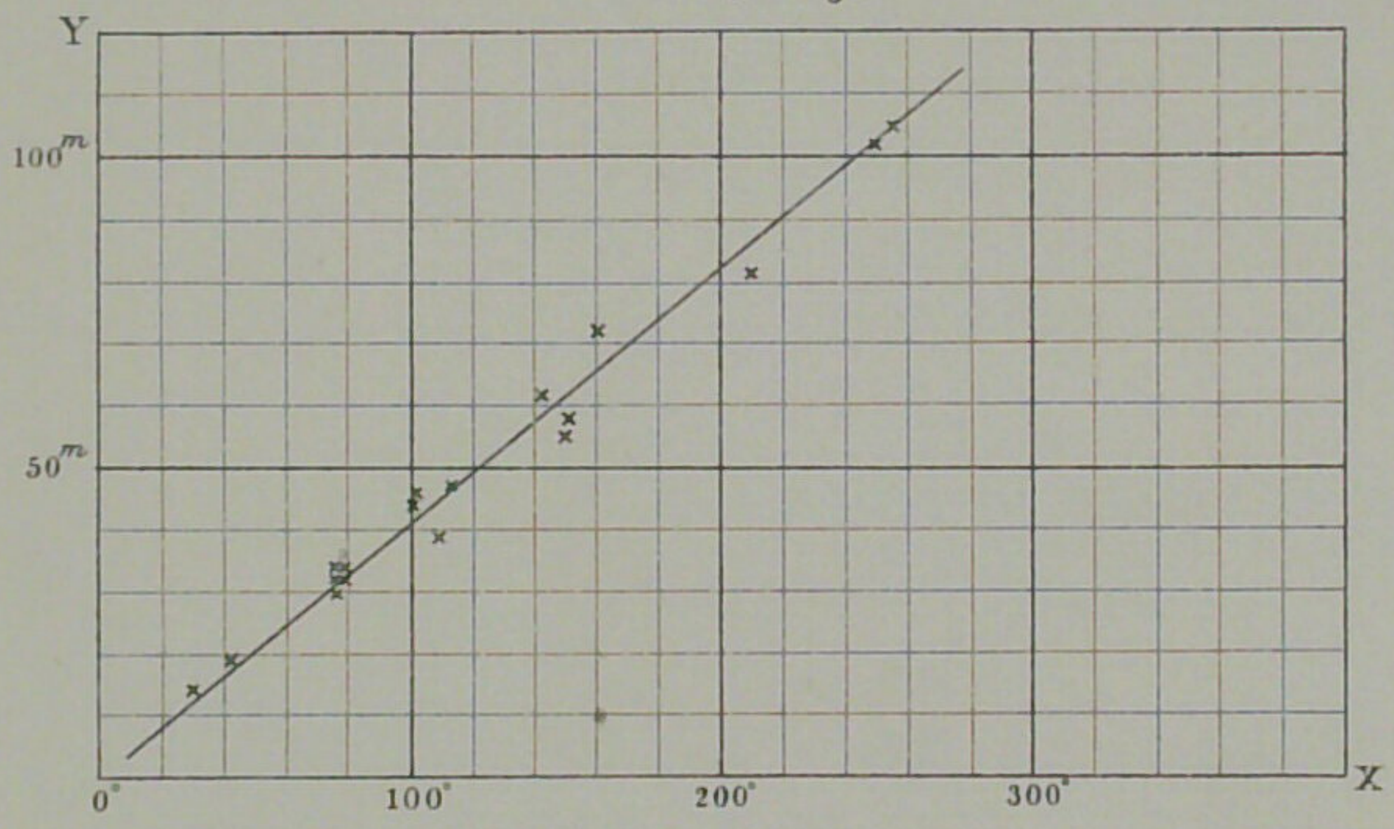
Fig. 2, b.

Guatemala earthquake:

Curve for P_2.



Curve for P_3.



Curve for P_5.

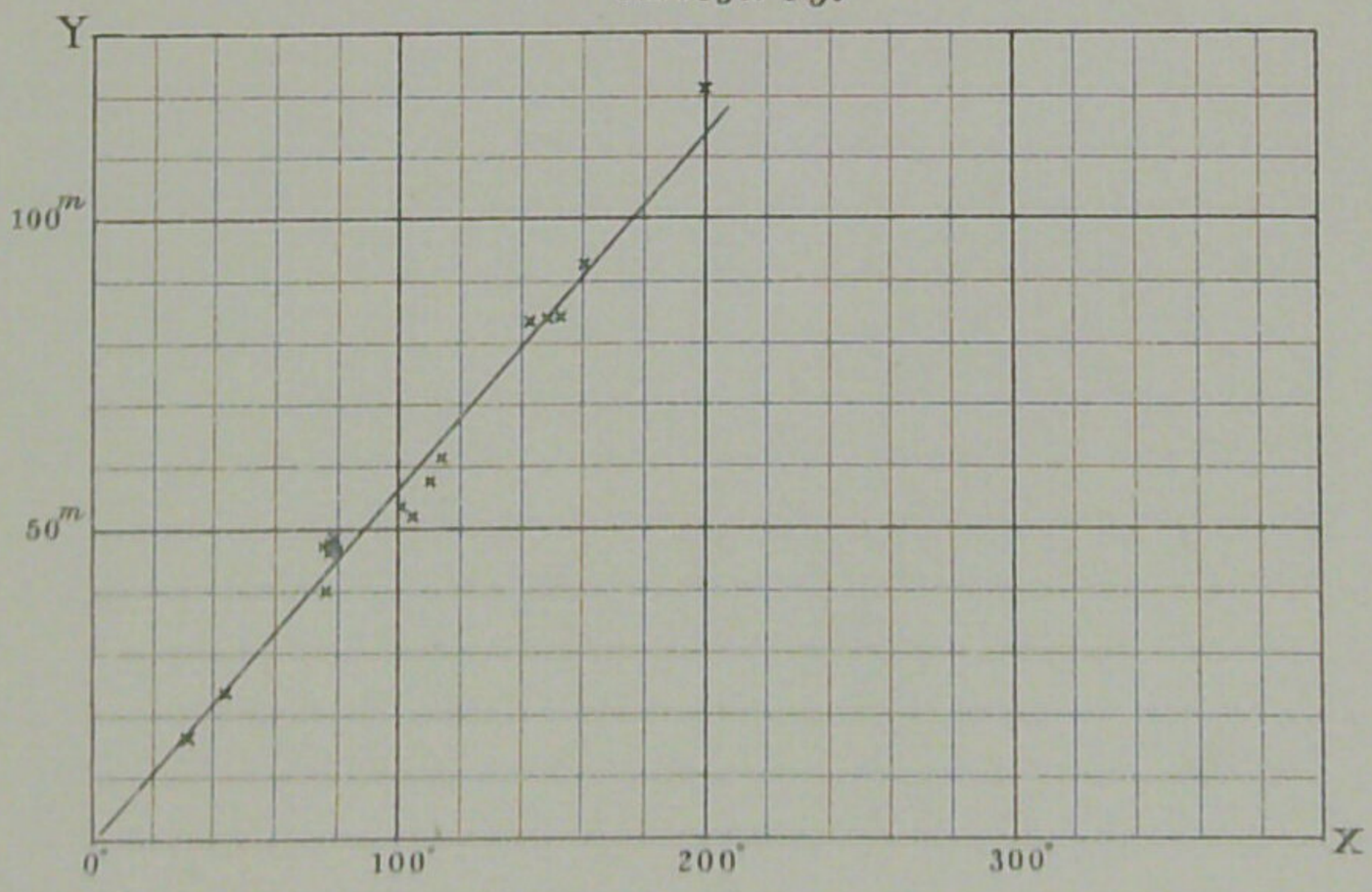
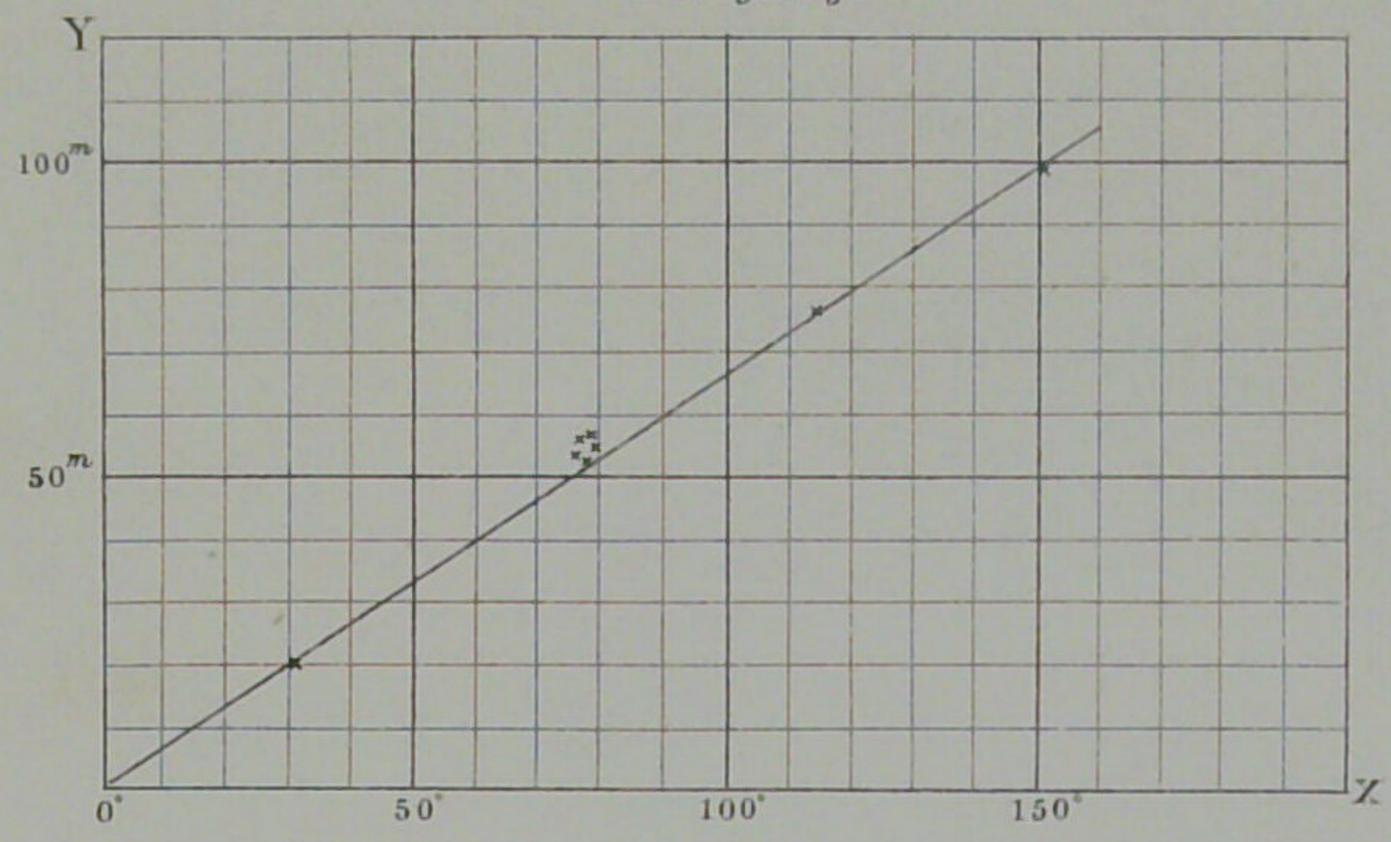


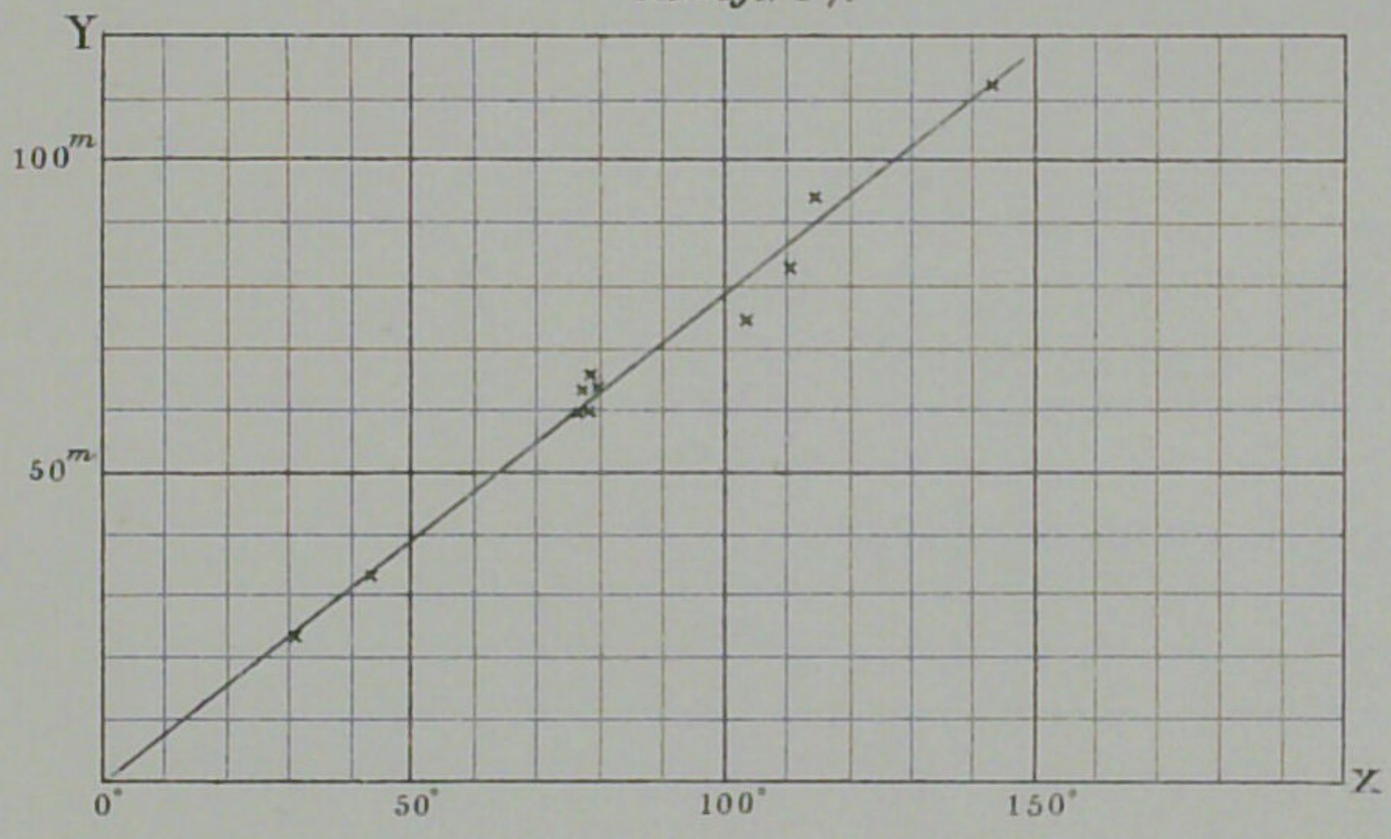
Fig. 2, c.

Guatemala earthquake:

Curve for P_6.



Curve for P_7.



Curve for P_8.

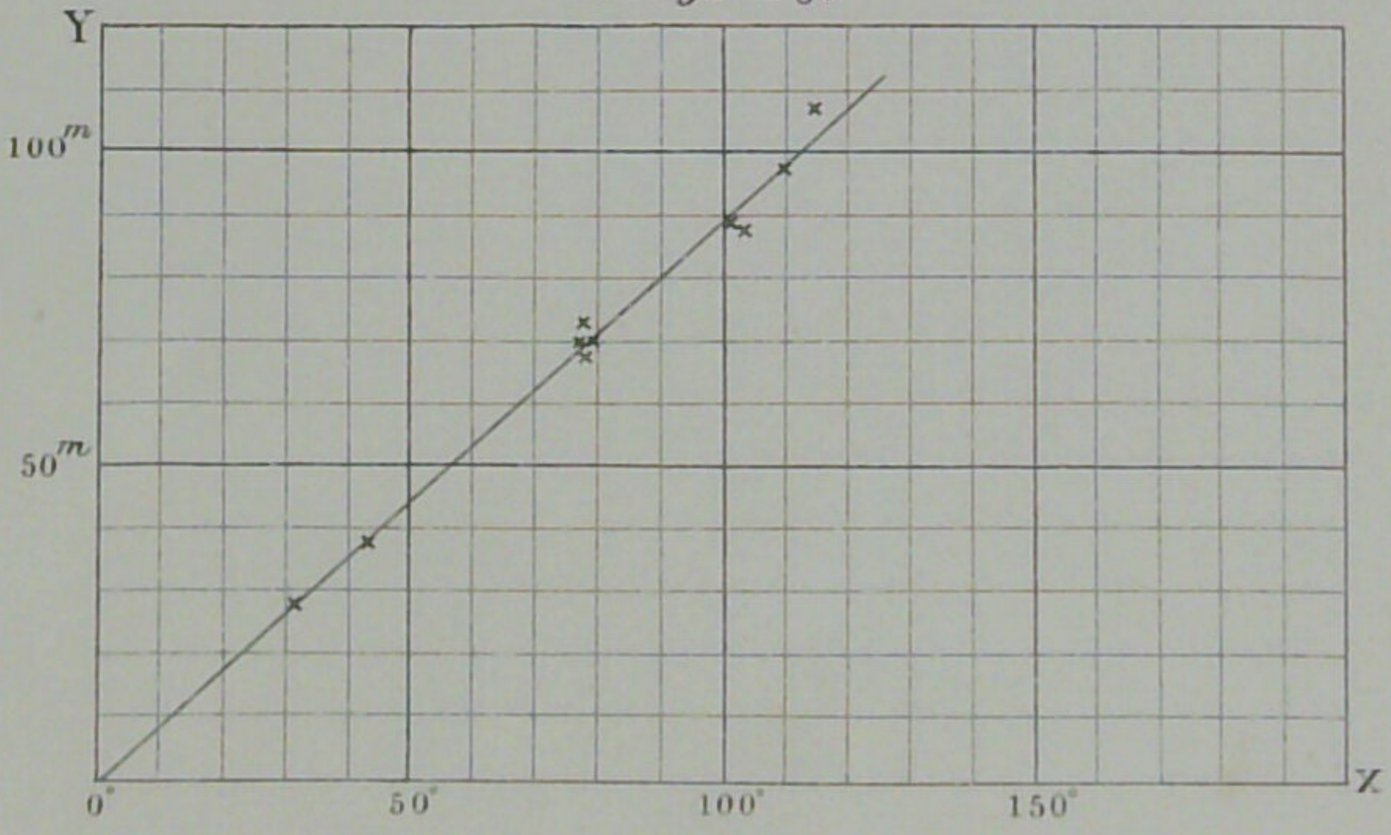


Fig. 3. Relation between the arcual epicentral distance from Tokyo and the time taken in transit by the different phases.

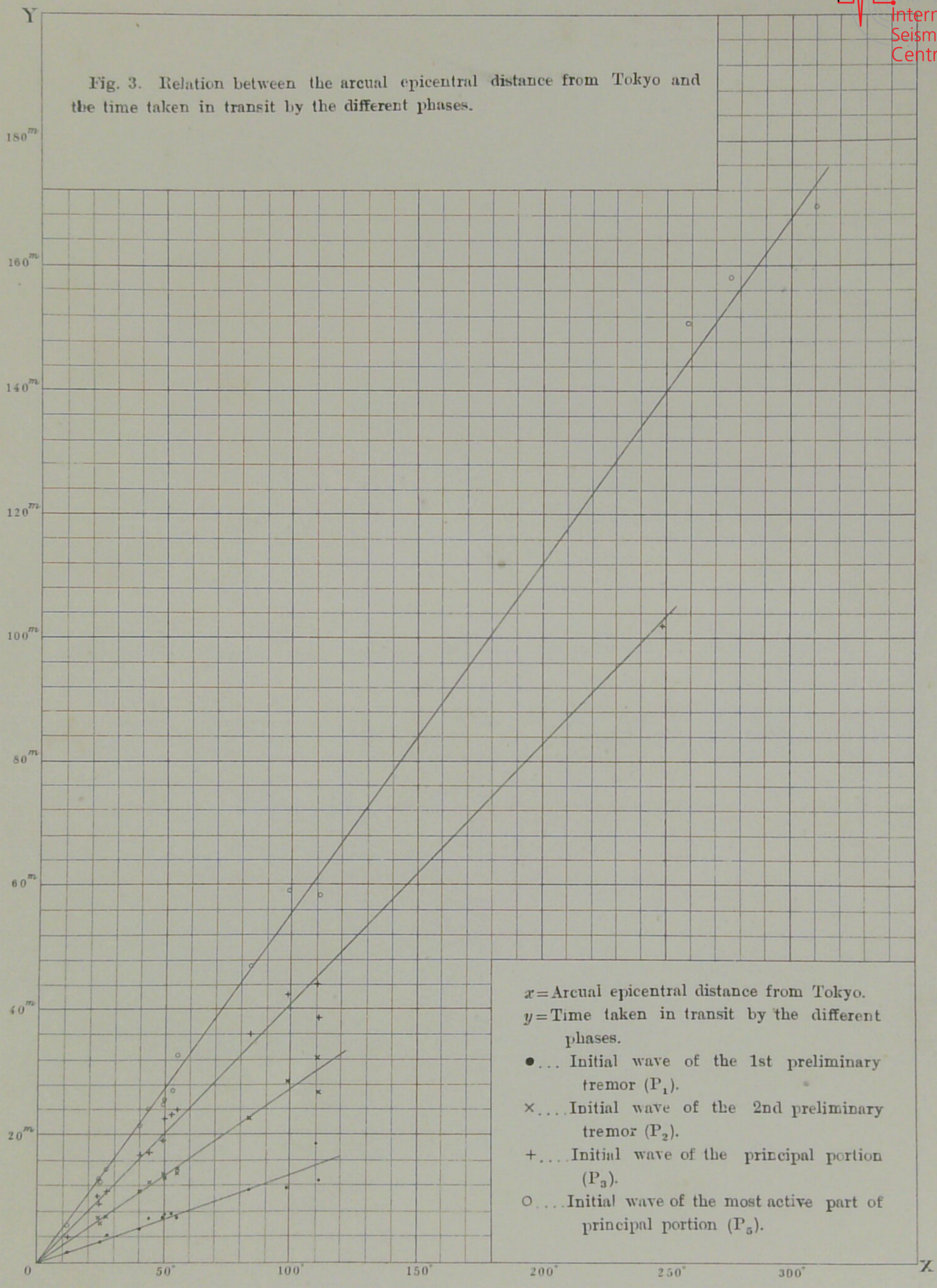


Fig. 4. Relation between arcual epicentral distance and the time taken in transit by the different phases.

x=Arcual epicentral distance.

y=Time taken in transit by the different phases.

●.... Initial phase of the 1st preliminary tremor.

×.... ,, 2nd ,, .

+.... ,, principal portion.

○.... ,, most active part of principal portion.