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MACRO-SEISMIC MEASUREMENT
IN TOKYO. I.

BY

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Introduction.

The present volume, which may be regarded as the continuation of the late Professor S. Sekiya's paper on the Tokyo earthquake measurement,* contains the analysis of the diagrams of the 220 earthquakes observed, with the exception of the first nine, between Sept. 1887 and July 1889, at three places in Tokyo, as follows :

Observing station.	Number of earthquakes observed.	Position of observing station.	
		Latitude, <i>N.</i>	Longitude, <i>E.</i>
Hongo (Seismological Institute.)	82	35° 42' 29''	139° 45' 53''
Hitotsubashi.	78	35° 41' 17''	139° 45' 35''
{ Central Meteorological Observatory.†	202		

The observations at Hongo (Seismological Institute) and at Hitotsubashi, which form the principal object of our examination, were made by Professor Sekiya mostly by means of Ewing's horizontal pendulum and vertical motion seismographs, which magnify the horizontal motion 4 to 5 times and the vertical 7 to 8 times. On the other hand, the observations at the Central Meteorological Observatory were made by means of a Gray-Milne seismograph, which magnifies the horizontal and vertical movements 6 and 4 times respectively. In each case,

* Jour. Sc. Coll. Imp. Univ., Tokyo, Vol. II, p.p. 57-75.

† The Central Meteorological Observatory is only 500 m to the south-west of Hitotsubashi.

the two horizontal components were in the east-west and north-south directions. Sometimes I have made also short references to the records given by *duplex pendulum seismographs* which write the horizontal motion, 6 or 7 times magnified, on a stationary glass plate.

The account of each earthquake is given more or less completely according to the following form.—

(1) Date and time of occurrence.

(2) Result of observation at the Central Meteorological Observatory. In cases of *strong* earthquakes, notes on the area of disturbance are also given.*

(The data in (1) and (2) are taken from the seismometrical reports of the Central Meteorological Observatory.)

(3) Detailed analysis of the seismograms obtained at Hitotsubashi and Hongo.

The times are always given in the *First Standard Japan Time*, or that of long. $135^{\circ}E$.

For finding the relation, if any, between the amplitude and period of vibration, I have constructed, in cases of some of the stronger earthquakes, tables giving these two elements of motion for the different vibrations, conveniently divided into groups in order of magnitude of the amplitude. In some cases, the examination was confined to a single component. If not specially mentioned, however, the measurement for the horizontal motion was made with reference to its two components, that is to say, the range of motion(2a) denotes the resultant horizontal displacement in each vibration.

* The extent of the disturbed area is given in sq. *ri*; 1 *ri* being very nearly equal to 4 km.

The *preliminary tremor*, *principal portion* and *end portion*, into which an earthquake motion may be divided, are defined as follows.— (1) The preliminary tremor is the introductory part, which consists of movements of small amplitude and of short period ; (2) the principal portion is the most active part which follows the preliminary tremor and consists of movements of large amplitude ; (3) the end portion denotes the feeble finishing part which follows the principal portion.

Ripples are those quick earthquake vibrations whose periods are small fractions of a second, generally superposed on slow principal undulations.

Intensity of motion. The intensity of ordinary, or non-destructive, earthquake motion is indicated as *slight*, *weak* or *strong*. A *slight* shock is one which is very feeble ; a *weak* shock is one whose motion is well pronounced but not so severe as to cause general alarm ; and finally a *strong* shock is one which is sufficiently sharp to throw down some furnitures, to cause people to run out of doors, etc.

A *tremor* denotes a very slight earthquake, whose amplitude is too small to be accurately measured.

Abbreviations.

The abbreviations used in the description of the seismograms are as follows.—

H.M. . . . Horizontal motion.

V.M. . . . Vertical motion.

2a . . . Range of motion, or double amplitude.

T . . . Period (complete) of vibration.

T_0 . . . Period of vibration corresponding to max. 2a.

$V = \frac{2\pi a}{T_0} = \text{Maximum velocity.}$

$$A = \frac{4\pi^2 a}{T_o^2} = \text{Maximum acceleration.}$$

2a is expressed in mm, and T_o and T each in second.

Macro-seismic motion.

The motion of an earthquake when observed at no very great distance from the origin consists generally of a set of different waves whose periods range from fractions of a second up to 1 minute or more. Now the maximum motion (2a) in ordinary earthquakes as observed at Hitotsubashi is on average about 0.7 mm, while the lowest limiting value of the the acceleration (A) of the sensible earthquake motion is about 17 mm per sec. per sec.* If we, for example, put $2a = 0.7$ mm. and $A = 17$ mm/s², we obtain $T^2 = \frac{4\pi^2 a}{A}$; therefore $T = 0.9$ s.

Similarly, if we put $2a = 5$ mm, and $A = 17$ mm/s², we obtain $T = 2.4$ s.

The above calculations show that, with the ranges of motion of 0.7 mm and 5 mm, the vibrations would not be sensible unless the period be smaller than 0.9s and 2.4s respectively. Now, as the motion is small in slight earthquakes, while the period is generally greater than 5 or 6 seconds in distant earthquakes;† so we may define the *macro-seismic motion* as a part of the earthquake motion whose period is, excepting cases of strong shocks, not longer than 2 or 3 seconds. Consequently the diagrams given by the ordinary Ewing or Gray-Milne seismographs, analyzed in the following pages, are to be regarded as indicating only the macro-seismic portions in the different earth-

* See the *Publications*, No.11.

† In the diagrams of distant earthquakes there are often vibrations whose period is less than 1 sec., but the 2a of these movements is always very small.

quakes, the instruments not being able to record accurately the motion with period longer than $2\frac{1}{2}$ or 3 sec.

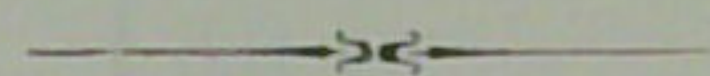
In No. 11 of the *Publications* I give a discussion of the analysis contained in the present volume, together with other miscellaneous notes.

Feb. 1902. Seismological Institute, Tokyo.

MACRO-SEISMIC MEASUREMENT IN TOKYO. I.

BY

F. OMORI, Dr. Sc.



Eqke No. 1. Sept. 26, 1885: 0.30.0 p.m.

Hitotsubashi; horizontal motion.

The earthquake consisted of gentle vibrations. Max. $2a = 5.0$ mm, $T_0 = 1.8$ s; $V = 8.7$ mm/sec., $A = 30.5$ mm/sec.² The relation between $2a$ and T of the horizontal motion is given in the following table.

HITOTSUBASHI; HORIZONTAL MOTION.

$2a$ (mm)	T (sec.)	$2a$ (mm)	T (sec.)		
5.0	1.8	1.9	1.5		
5.0	2.0		0.92		
4.5	2.1		1.1		
4.3	2.6		1.1		
4.1	1.7		1.2		
4.0	1.8		1.4		
3.5	1.5	1.6	1.1		
				3.3	1.7
				3.1	1.4
				2.9	1.8
				2.8	1.5
				2.5	1.8
2.5	2.1	1.3	1.0		
				2.3	1.1
				2.1	1.5
				2.1	1.2
				2.0	1.1
				2.0	1.2
2.5	1.1	1.4	0.95		
				2.3	1.5
				2.1	1.4
				2.1	1.1
				2.0	1.5
				2.0	1.2
2.5	1.5	1.4	1.4		
				2.3	1.1
				2.1	1.5
				2.1	1.4
				2.0	1.5
				2.0	0.84
2.5	1.1	1.4	1.2		
				2.3	1.1
				2.1	1.5
				2.1	1.4
				2.0	1.5
				2.0	0.84

2a (mm)	T (sec.)	2a (mm)	T (sec.)
1.1	0.84	0.7	0.44
"	"	"	0.64
"	0.89	"	0.74
"	0.92	"	0.47
1.0	0.77	"	0.92
"	0.87	0.6	0.61
0.9	0.80	"	0.58
"	0.54	"	0.80
"	1.1	0.5	0.48
0.8	0.69	0.3	0.77
"	0.80	"	
"	1.0		

Eqke No. 2. July 2, 1886 : 0.33.6 p.m.

This was a moderately strong earthquake, the motion being chiefly in the *EW* component.

Hitotsubashi ; horizontal motion.

Max. $2a = 1.5$ mm, $T_0 = 0.83$ s ; $V = 5.7$ mm/sec., $A = 43.$ mm/sec.² The relation between $2a$ and T of the horizontal motion is given in the following table.

HITOTSUBASHI : HORIZONTAL MOTION.

2a (mm)	T (sec)	2a (mm)	T (sec.)
1.5	0.83	0.75	0.83
1.3	0.86	0.75	0.68
1.5	0.86	0.75	0.75
1.1	0.79	0.75	0.71
1.0	0.90	0.75	0.79
1.0	0.71	0.75	0.83
1.0	0.83	0.75	0.75
0.9	0.83	0.75	0.75
0.9	0.86	0.75	0.86
0.9	0.86	0.75	0.86
0.9	0.83	0.75	0.68
0.9	0.79	0.75	0.83
0.9	0.90	0.70	0.71
0.9	0.83	0.70	0.68
0.8	0.75		

0.65	} 0.26 (mean)	0.79	} 0.78 (mean)	} 0.26 (mean)	} 0.78 (mean)	
0.65		0.79				
0.60		0.68				
0.60		0.56				0.30
0.60		0.83				0.30
0.55		0.75				0.30
0.50		0.75				0.25
0.50		0.86				0.25
0.45		0.90				0.25
0.40		0.83				0.25
0.40		0.83				0.25
0.38		0.83				0.25
0.38		0.79				0.20
0.38		0.75				0.79
0.38		0.75				0.79

From the above table, it will be seen that there was in this case no marked variation of the period. The following results have been obtained from the measurement of the vibrations in the very end part of the earthquake.

HITOTSUBASHI : HORIZONTAL MOTION, CONT.

2a (mm).	Number of Vibrations.	Average period (sec.)
Very small	3	0.73
"	3	0.75
"	2	0.70
"	3	0.77
"	3	0.69

Eqke No. 3. Dec. 26, 1886 : 5.48.5 p.m.

Hongo.

Horizontal motion. The motion consisted of small vibrations which were at first quick and irregular, but became, after a short interval, smooth and regular.

Vertical motion. The motion was maximum at the commencement,

gradually diminishing towards the end. The period remained very nearly constant as will be seen from the following table.

HONGO; VERTICAL MOTION.

	2a (mm)	Number of vibrations.	Average period (sec.)
At the commencement of the eqke.	Very small.	5	0.43
Towards the end.	„	7	0.39
„	„	4	0.43

} 0.42 (mean)

Eqke No. 4. June 20, 1887 : 8.38.30 a.m.

Hitotsubashi.

The motion was rather greater in the *EW* than in the *NS* component, the period remaining constant.

HITOTSUBASHI: *EW* COMPONENT.*

2a (mm)	Number of vibrations.	Average period (sec.)
0.45	3	0.86
0.38	3	0.90
0.38	3	0.94
0.38	2	1.0
0.38	3	0.94
0.38	3	0.94
0.30	3	0.98
0.25	3	0.94
Very small	3	0.96
„	3	0.96

} 0.94 (mean)

Hongo.

The motion was very small in all the three components, the period of vibration being as follows.

Hongo ; horizontal motion.

The motion was much greater in the *NS* than in the *EW* component there being no vertical motion.

HONGO ; *NS* COMPONENT.

2a (mm).	Number of vibrations.	Average period (sec).
0.12	4	0.44
Very small	5	0.44
—	4	0.47
—	4	0.41
—	5	0.42
—	2	0.39
—	4	0.42

} 0.43 (mean).

Eqke No. 6. June 30, 1887 : 8.0.35 a.m.

Hongo.

This was a very small earthquake.

Horizontal motion. The max. 2a was less than 0.1 mm ; the motion, which was almost entirely in the *NS* component, consisting of regular vibrations. The diagram indicated no preliminary tremour.

HONGO ; *NS* COMPONENT.

2a (mm).	Number of vibrations.	Average period (sec.).
Small.	3	0.45
"	3	0.45
Very small.	5	0.46
"	5	0.44
"	2	0.43
"	2	0.41
"	5	0.44
"	5	0.42
"	5	0.42
"	2	0.43

} 0.44 (mean).

Vertical motion. The duration of the vertical motion was somewhat shorter than that of the horizontal. The period remained perfectly constant, the average value, deduced from 39 vibrations, being 0.18 s. The max. $2a$ was very small.

Eqke No. 7. July 2, 1887 : 3.16.24 p.m.

Hongo.

Horizontal motion. The motion occurred equally in the two horizontal directions and consisted of small regular vibrations, whose period remained perfectly constant in each component. The average period was as follows :--

$EW \dots\dots 0.72$ s (deduced from 30 vibrations);
 $NS \dots\dots 0.44$ s („ „ 41 „).

The origin of the earthquake was situated due *W* from Tokyo, so that the *EW* component may be taken as representing the *normal vibration*.

Vertical motion. The motion, which was maximum at the commencement and thence gradually diminished, consisted of small regular movements whose average period, deduced from 18 vibrations, was 0.17s.

Eqke No. 8. July 12, 1887 : 3.7.42 p.m.

This was a very small earthquake.

Hitotsubashi.

Horizontal motion. The motion consisted of regular vibrations, the max. $2a$ being 0.14 mm in the *EW* and 0.1 mm in the *NS* component. The average period was as follows :—

$EW \dots\dots 0.71$ s (deduced from 28 vibrations);
 $NS \dots\dots 0.74$ s („ „ 9 „).

Hongo.

The motion which consisted of vibrations of a constant period, was almost entirely in the *NS* component. The max. $2a$ was 0.14 mm, and the average period, deduced from 28 vibrations in the *NS* component, was 0.46s. There was no vertical motion.

Eqke No. 9. July 22, 1887 : 8.27.0 p.m.

This was an earthquake of moderate intensity.

Hongo.

Horizontal motion. The *NS* component consisted of regular movements of constant period, whose max. $2a$ was 0.25 mm and whose average period, deduced from 53 vibrations, was 0.46s. On the other hand, the *EW* component consisted of slow gentle movements of variable period, whose max. $2a$ was 0.4 mm and whose average period deduced from 15 vibrations, was about 1.0 sec.

Vertical motion. The vibrations occurred only in the earlier part of the earthquake. The $2a$ was very small, the average period, deduced from 22 vibrations, being 0.14 s.

Eqke No. 10. Sept. 2, 1887 ; 5.52.49 p.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 10s.

Direction. *E-W*.

Max. H. M. 0.4 mm (period = 0.7s).

Max. V. M. Small.

Character. Quick.

Hitotsubashi.

Horizontal Motion. Duration = 50s.

Max. $2a = 0.21$ mm, $T_0 = 0.54$ s ; $V = 1.2$ mm/s, $A = 14.2$ mm/s.² The average period was as follows :—

EW 0.52 s (deduced from 24 vibrations) ;

NS 0.55 s („ „ 16 „).

Hongo.

Horizontal motion. The motion consisted at first of very quick vibrations. After a short time interval these *ripples* disappeared, and there followed regular and somewhat larger movements, whose period remained constant till the end of the earthquake, and whose average period, deduced from 68 vibrations in the *NS* component, was 0.44s. The motion was chiefly in the *NS* component.

$$\text{Max. } 2a = 0.2 \text{ mm, } T_o = 0.45 \text{ s; } V = 1.4 \text{ mm/s, } A = 19.5 \text{ mm/s}^2.$$

Vertical motion. The vertical motion consisted of a series of extremely small regular vibrations, whose maximum occurred at the commencement. The period was constant, the average value, deduced from 40 vibrations, being 0.16 s. It may be noted that the character of the vertical motion was much different from that of the horizontal, the maximum in the latter component occurring some seconds after the start when the movements became free of the superposed ripples. It seems probable, however, that the vertical vibrations and the horizontal ripples belong to one and the same class of waves.

Eqke No. 11. Sept. 3, 1887; 4.50.30 a.m.

A tremor observed at the *Cent. Met. Observatory.*

Eqke No. 13. Sept. 5, 1887; 3.23.23 p.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 6 m.

Direction. *SE—NW.*

Max. H.M. 25.7 mm (period = 2.3s).

Max. V.M. 6.5 mm (period = 0.8s)

Character. Quick

Remark. “The earthquake began with tremors which lasted 7s. Then the horizontal motion became active and indicated 34 large vibrations; the maximum having occurred at the 32nd second. At the 46th second the motion became small, but after a short interval it increased again, being more or less active for the first 1m 50s. The maximum of the vertical motion, whose character was sharp from the commencement, occurred at the 18th second, or 14s earlier than the maximum horizontal motion. The vertical motion was more or less active till the 56th second. This earthquake was the strongest in this year next to that of the 15th of January.

“The total land area of disturbance was 4660 sq. *ri* and extended over the following 16 provinces :— Suruga, Kai, Izu, Sagami, Musashi,

Awa, Kazusa, Shimosa, Hitachi, Kotsuke, Shimotsuke, Shinano, Iwaki, Iwashiro, Echigo and Rikuzen. The motion was felt *strongly* in the eastern part of Sagami, eastern part of Musashi, Awa, Kazusa, Shimosa, Hitachi, eastern part of Kotsuke, eastern part of Shimotsuke, and in the southern portion of Iwaki. The area of *violent* motion was about 150 sq. *ri* and extended over the eastern portion of Kazusa, eastern portion of Shimosa and the south-eastern portion of Hitachi.

“The reports from some of the places in the *violently* or *strongly* shaken area were as follows.—

“*Shimosa.* In the Katori District, vertical motion was felt first, soon followed by horizontal shakings, which caused some damage such as cracking of house walls, falling down of roof tiles, overturning of furnitures, overflowing of liquids, etc. An old ware house was overthrown, while several dwelling houses were thrown out of the vertical position. Some *shōu* brewers sustained losses from the fracturing of the chimneys and the overturning of the large vessels which contained several thousand *koku* of *shōu*. Porcelain dealers had also much of their articles broken. In Kaijō District, house walls were cracked, liquids overflowed and people generally ran out of doors. In Sosa District, some ware houses were damaged, the motion having been so violent that a man working on the roof of a house was thrown down.

“*Kazusa.* In the Nagara District, the earthquake began with vertical tremors, followed after a short interval by horizontal shakings, which became so strong that people ran out of houses. Some *dozo* (Japanese ware houses) were cracked, waters contained in tubs overflowed towards east or north and loosely piled fagots fell down towards *NE*. Porcelain dealers sustained losses from the overturning of their articles.

“*Hitachi.* In the Kajima District the shaking was felt simultaneously with sounds. The water which filled a tub to about 4 inches from the mouth partly overflowed toward *S*. In some of the other districts pendulum clocks were stopped and furnitures were overthrown.

“In *Kazusa*, *Shimosa* and the eastern part of *Hitachi*, this earthquake was the strongest next to that in the winter of 1884.”

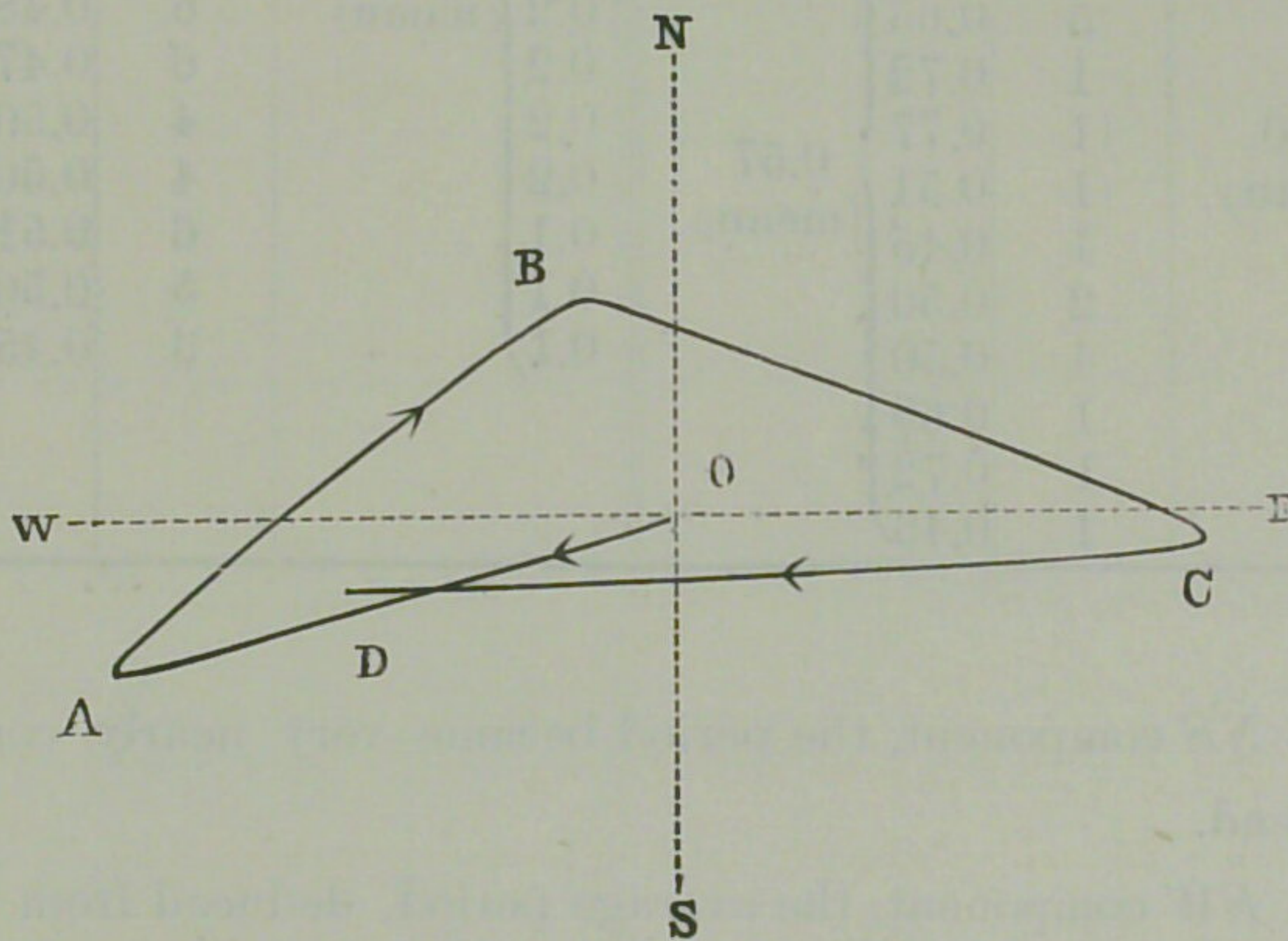
Hongo.

The horizontal motion of this earthquake was much greater, but of slower period, than that of the earthquake of Jan. 15th, 1887. The vertical motion was small.

Horizontal motion. The duration was as follows:—

<i>EW</i> component	$4\frac{1}{2}$ m ;
<i>NS</i> „	$3\frac{1}{2}$ m.

The motion was much greater in the *EW* than in the *NS* component, probably because the origin was to the east of Tokyo. At first there were some superposed *ripples*, which, however, were insignificant.



Scale : 4.7/1

The preliminary tremor lasted 15s, when took place the following maximum vibration (*OABCD* in the accompanying figure):—

Max. $2a = 15\text{mm}$, Direction $N 84^\circ E$, $T_o = 3.0\text{s}$; $V = 15.7 \text{ mm/s}$,
 $A = 33\text{mm/s}^2$

During the first 40s, the motion was complicated, but thereafter it became gradually regular. The vibrations in the *NS* component were quicker and more regular than those in the *EW* component. The relation between $2a$ and T of the vibrations in the *NS* component after 40s from the commencement is given in the following table.

HONGO : NS COMPONENT.

2a(mm)	Number of vibrations	T (sec.)	2a(mm)	Number of vibrations	T (sec.)	
1.7	1	0.9	0.3	2	0.54	
1.3	1	0.81		2	0.45	
1.0	1	0.72		1	0.41	
1.0	1	0.9		8	0.54	
0.9	1	0.68		0.2	3	0.43
0.8	1	0.63		0.2	3	0.42
0.8	1	0.63		0.2	6	0.47
0.7	1	0.68		0.2	3	0.45
0.6	1	0.50		0.2	6	0.48
0.6	1	0.59		0.2	6	0.47
0.6	1	0.45	0.2	4	0.50	
0.6	5	0.65	0.2	4	0.50	
0.6	1	0.72	0.2	6	0.51	
0.56	1	0.77	0.1	5	0.50	
0.5	1	0.51	0.1	3	0.45	
0.4	1	0.45				
0.4	2	0.50				
0.4	4	0.50				
0.4	1	0.60				
0.4	1	0.72				
0.36	1	0.45				

In the *NS* component, the period became very nearly constant towards the end.

In the *EW* component, the average period, deduced from 11 vibrations in the end portion, was 1.3s.

Vertical motion. Duration=80s. The motion, which was more or less active during the first 40s, was at first irregular but became regular towards the end. There were two equal maxima which occurred respectively at the 15th and 18th seconds :

$$\text{Max. } 2a = 0.48\text{mm, } T_0 = 0.61\text{s; } V = 2.5 \text{ mm/s, } A = 25\text{mm/s.}^2$$

It will be observed that the first vertical maximum occurred simultaneously with the maximum in the horizontal component.

The relation between $2a$ and T of the vertical motion is given in the following table.

HONGO : VERTICAL MOTION.

$2a$ (mm)	Number of vibrations.	Average T (sec.)	$2a$ (mm)	Number of vibrations.	Average T (sec.)	
0.50	1	0.51	Very small	4	0.15	
0.44						0.54
0.31						(mean)
0.25	1	0.40	"	7	0.18	
0.25						0.39
0.21						(mean)
0.19	1	0.36	"	2	0.18	
0.15	1	0.27	"	6	0.17	
0.15						0.28
0.13						
0.13	3	0.27	"	3	0.15	
0.13						(mean)
0.13						0.16
0.06	1	0.33	"	3	0.14	
	2	0.28	"	4	0.15	

Eqke No. 13. Sept. 4 1887 :—

Not observed at the *Cent. Met. Observatory.*

Hitotsubashi.

Horizontal motion. This was a very small earthquake which consisted of gentle shakings, the motion being chiefly in the *EW* direction.

Max. $2a=0.3\text{mm}$, $T_0=0.8\text{s}$; $V=1.2\text{mm/s}$, $A=9.3\text{mm/s}^2$. The average period, deduced from 44 vibrations in the *NS* component, was 0.72s.

Vertical motion. Very slight.

Eqke No. 14. Sept. 6, 1887 :—

Not observed at the *Cent. Met. Observatory.*

Hitotsubashi.

Duration = 120s. The motion, which was slightly greater in the *EW* than in the *NS* direction, consisted of a series of very regular gentle vibrations, there being no vertical component. The following maximum motion occurred at the 4th second :—

Max. $2a=0.64$ mm, $T_o=1.1$ s; $V=1.8$ mm/s, $A=10.4$ mm/s².

The average period, deduced from 24 vibrations in the *EW* component, was 0.83s. The motion in the *NS* component was irregular.

Hongo.

The motion, which consisted of smooth regular vibrations, was much greater in the *EW* than in the *NS* component.

Eqke No. 15. Sept. 8, 1887; 3.55.0 p.m.

A tremor observed at the *Cent. Met. Observatory.*

Eqke No. 16. Sept. 11, 1877; 9.20.0 a.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 25s.

Direction. *E-W.*

Max. H.M. Small.

Character. Gentle.

Eqke No. 17. Sept. 13, 1887; 8.16.52 p.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 12s.

Direction. *SW-NE.*

Max. H.M. 0.2mm (period=1.2s).

Character. Gentle.

Hongo.

Duration=65s. The motion, which occurred equally in the two horizontal components, consisted of gentle vibrations, there being no vertical component.

Max. $2a=0.05$ mm, $T_o=0.6$ s; $V=0.3$ mm/s, $A=2.7$ mm/s². The motion, which was at first irregular, became afterwards regular, the average period being as follows :—

(*EW*) 1.4s (deduced from 12 vibrations);

(*NS*) 0.50s („ „ 26 „).

Eqke No. 18. Sept. 15, 1887; 4.41.41 p.m.

Observation at the *Cent. Met. Observatory* :—

- Duration. 3s.
- Direction. *E-W*.
- Max.H.M. 0.2mm (period=0.3s).
- Character. Quick.

Eqke No. 19. Sept. 25, 1887 ; 8.56.11 a.m.

Observation at the *Cent. Met. Observatory* :—

- Duration. 2m.
- Direction. *ESE-WNW*.
- Max. H. M. 1mm (period=1.8s).
- Max. V. M. Small.
- Character. Gentle.

Hitotsubashi

Duration=3m. The motion was much larger in the *EW* than in the *NS* component.

Max.2a=1.7mm, Direction *S 70° W*, $T_o=0.84s$; $V=6.4 \text{ mm/s}$, $A=47.6 \text{ mm/s}^2$. The average period, deduced from 13 vibrations in the *EW* component, was 0.77s.

The *Duplex Pendulum* at Hitotsubashi indicated two principal directions of motion, namely, *ENE-WSW* and *ESE-WNW*, the amplitude being greater in the former direction.

Hongo.

The duration was as follows :—

- (*EW*).....116s;
- (*NS*).....87s.

The preliminary tremor lasted 1.2s, when the following maximum motion took place :—

Max. 2a=0.5mm, $T_o=0.5s$; $V=3.1 \text{ mm/s}$, $A=39.5 \text{ mm/s}^2$.

In the *end portion* of the *NS* component, when the superposed ripples disappeared, the average period was 0.48s. The motion in the corresponding portion of the *EW* component consisted of slow undula-

tions of an average period of 0.93s, superposed with smaller ones of an average period of about 0.53s. These latter vibrations existed also in the earlier part of the earthquake and had an average period of 0.42s. Vertical motion did not exist.

The *Duplex Pendulum* at Hongo indicated the same two principal directions of motion as at Hitotsubashi.

Eqke. No. 20. Nov. 15, 1887 ; 3.54.51 p.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 2m.

Direction. *SE-NW*.

Max. H.M. 0.4mm (period = 2.4s).

Character. Gentle.

Hongo.

Horizontal motion.

Duration = 70s. The motion was greater in the *EW* than in the *NS* direction, the vertical component being very small.

Max. $2a = 0.16\text{mm}$, $T_0 = 0.6\text{s}$; $V = 0.8\text{ mm/s}$, $A = 8.8\text{ mm/s}^2$.

Vertical motion.

Max. $2a = 0.06\text{mm}$. $T_0 = 0.5\text{s}$; $V = 0.4\text{ mm/s}$, $A = 4.7\text{ mm/s}^2$.

Eqke No. 21. Nov. 20, 1887 ; 0.2.81 p.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 45s.

Direction. *SWS-NEN*.

Max. H.M. 0.2mm (period = 0.5s).

Character. Quick.

Hitotsubashi.

Horizontal motion. Duration = 3m. The motion was greater in the *NS* than in the *EW* component.

The average period deduced from 16 vibrations in the *NS* component, was 0.63s.

Vertical motion. Duration = 40s.

Max. $2a = 0.3\text{mm}$, $T_o = 0.5\text{s}$; $V = 1.9\text{ mm/s}$, $A = 23.7\text{ mm/s}^2$.

The average period, deduced from 22 vibrations, was 0.45s.

Hongo.

Horizontal motion. Duration = 57s.

The diagram indicated no preliminary tremor, but began at once with the max. $2a$ of 0.24mm in the *NS* and 0.08mm in the *EW* direction. The motion, which was much greater in the *NS* than in the *EW* component, consisted, in the former, during the first 8.1s of quick and irregular vibrations of an average period of 0.18s; thereafter the vibrations became regular and slow, the average period, deduced from 60 vibrations, being 0.47s. In the *EW* component it was difficult to count the number of vibrations.

Vertical motion. Duration = 12.5s.

The vertical motion existed in a comparatively large amount and consisted of a series of regular vibrations of an average period of 0.18s. The max. $2a$ of 0.16mm occurred soon after the commencement.

Eqke No. 22. Nov. 23, 1887; 6.5.0 p.m.

A tremor observed at the *Cent. Met. Observatory.*

Eqke No. 23. Nov. 30, 1887; 9.24.18 a.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 90s.

Direction. *SES-NWN.*

Max. H. M. 1.3mm (period = 1.2s).

Character. Gentle.

Remark. The motion was at first small. The maximum vibration occurred at the 15th second.

Hitotsubashi.

Horizontal motion. Duration = 100s. The motion, which was chiefly in the *EW* direction, consisted of gentle vibrations.

Max. $2a = 0.64\text{mm}$, Direction *SE*, $T_o = 0.96\text{s}$; $V = 2.1\text{ mm/s}$,

$A = 13.6\text{ mm/s}^2$.

The average period was 0.83s.

Hongo.

Horizontal motion. Duration = 90s.

The preliminary tremor lasted 2.0s. The motion which was greater in the *NS* than in the *EW* component, was during the first 10s superposed with small ripples of an average period of 0.16s; thereafter the vibrations became simple and regular.

Max. $2a = 0.6\text{mm}$, *Direction S*, $T_0 = 1.3\text{s}$; $V = 1.5 \text{ mm/s}$,

$A = 7.0 \text{ mm/s}^2$

The average period in the *NS* component was as follows :—

during the 1st 9.8s Aver. period = 0.45s ;

„ „ next 18.0s „ „ = 0.45s (max. $2a = 0.3\text{mm}$) ;

„ „ „ 17.5s „ „ = 0.44s („ „ = 0.18 „) ;

„ „ „ 5.7s „ „ = 0.45s (motion very small).

In the *EW* component, the vibrations were irregular but had an average period of about 0.6s; towards the very end they became small and slow and had an average period of 0.77s.

Vertical motion. Duration = 45s.

The vertical motion, whose amount was comparatively large, consisted of a series of regular vibrations, whose max. $2a$ was 0.06mm, and whose average period was as follows :—

50 vibrations during the 1st 8.5s gave an aver. period of 0.21s ;

50 „ „ „ next 8.5s „ „ „ „ „ 0.21s,

50 „ „ „ „ 8.5s „ „ „ „ „ 0.21s.

The motion was small at the commencement, but the preliminary tremor was not well defined.

Eqke No. 24. Dec. 5, 1887 ; 0,57.16 p.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 15s.

Max. H. M. Very small.

The *Duplex Pendulum* at *Hongo* indicated very small movements, chiefly in the *SES—NWN* direction.

Eqke No. 25. Dec. 8, 1887 : 8.3.0 p.m.

Not observed at the *Cent. Met. Observatory* :—

Hitotsubashi.

Duration = 60s. The motion was chiefly in the *EW* direction.

Max. $2a = 0.2\text{mm}$, $T_o = 0.8\text{s}$; $V = 0.8\text{ mm/s}$, $A = 6.2\text{ mm/s}^2$

The average period was 0.8s.

Hongo.

Duration = 70s. The motion, which consisted of regular gentle vibrations, was greater in the *NS* than in the *EW* direction; there being no vertical component.

Max. $2a = 0.2\text{mm}$, $T_o = 0.5\text{s}$; $V = 1.3\text{ mm/s}$, $A = 15.8\text{ mm/s}^2$

The average period, deduced from 88 vibrations in the *NS* component, was 0.46s.

Eqke No. 26. Dec. 11, 1887 ; 9.55.47 p.m.

Observed as a tremor at the *Cent. Met. Observatory*.

The *Duplex Pendulum* at *Hitotsubashi* recorded motion chiefly in the *SE—NW* direction.

Eqke No. 27. Dec. 14, 1887 ; 10.55.9 p.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 150s.

Direction. *SES—NWN*.

Max. H.M. 0.3mm (period = 2s).

Character. Gentle.

The *Duplex Pendulum* at *Hitotsubashi* recorded motion chiefly in the *ENE—WSW* direction.

Eqke No. 28. Dec. 16, 1887 ; 8.28.21 a.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 120s.

Direction. *ESE—WNW*.

Max. H.M. 2.5mm (period = 1.5s).

Max. V.M. 0.3mm (period = 0.4s).

Character. Quick.

Remark. The preliminary tremor lasted for 7s, when the horizontal motion became suddenly active, the vertical motion appearing at the same moment. After 10s the intensity began gradually to diminish.

Hongo.

Horizontal motion. Duration = 100s. The preliminary tremor lasted for 3s, when the following maximum motion suddenly took place :—

$$\text{Max. } 2a = 2.4\text{mm, Direction } N 15^\circ W, T_o = 0.8\text{s ; } V = 9.4\text{mm/s,}$$

$$A = 74 \text{ mm/s}^2.$$

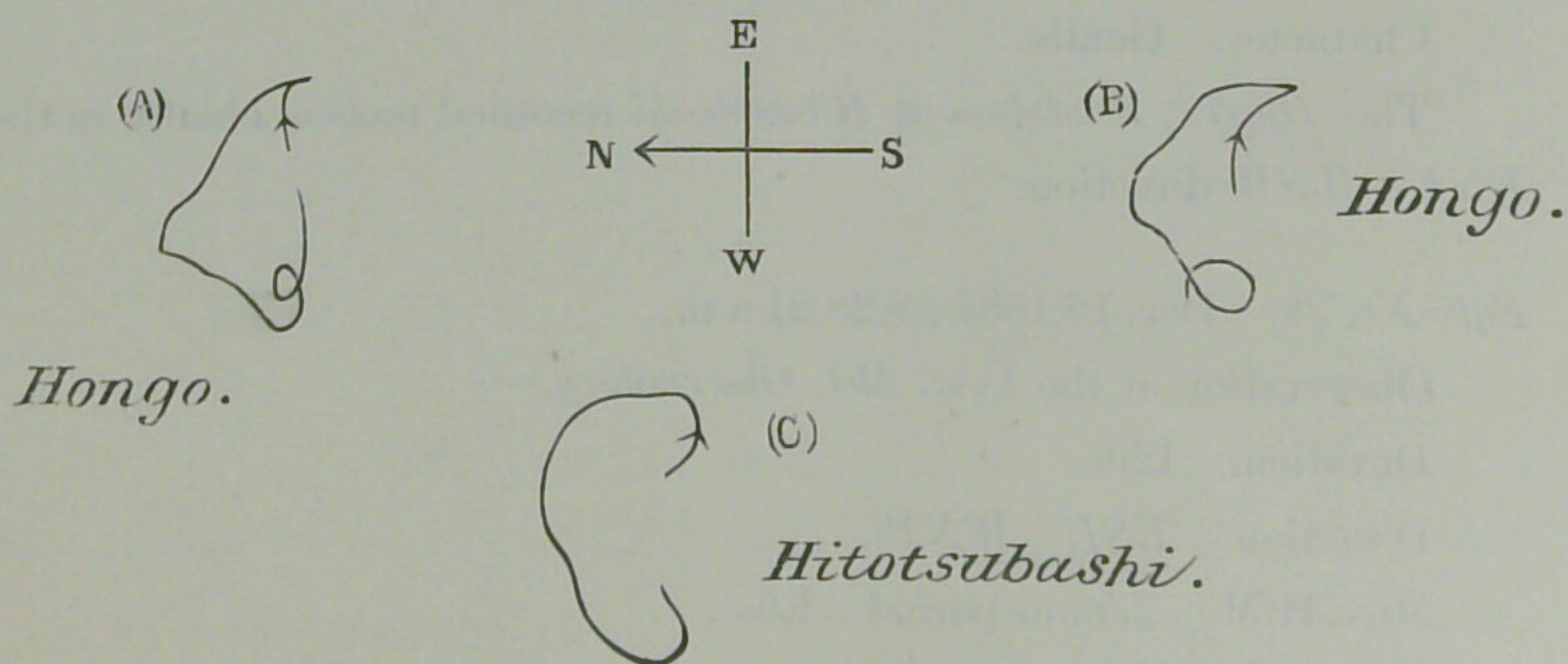
There was no corresponding prominent vibration in the vertical component. The movements, which followed the maximum, were much smaller ; their average period, deduced from 114 vibrations in the *NS* component, being 0.53s. The ripples existed till about 23rd second.

Vertical motion. Duration = 50s. For the first 18s, the motion consisted of nearly uniform quick vibrations, there being no prominent large displacement.

$$\text{Max. } 2a = 0.11\text{mm, } T_o = 0.25\text{s ; } V = 1.4 \text{ mm/s, } A = 34.8 \text{ mm/s}^2$$

After the 18th second the motion became abruptly very small.

The two *Duplex Pendulums* at Hongo gave almost identical diagrams (*A* and *B* in the accompanying figure), which show that the very first active motion was towards *E*, followed by two nearly equal displacements (= 2.4mm) directed respectively toward *NW* and *SE*. The rest of the shaking was small.



The *Duplex Pendulum* at *Hitotsubashi* gave a diagram (*C* in the accompanying figure) very similar to those at *Hongo*; the maximum motion (= 2.8mm) was directed toward *SW*.

Eqke No. 29. Dec. 17, 1887 ; 0.17.8 a.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 10s.

Max. H.M. Small.

Character. Quick.

Hitotsubashi.

The *Duplex pendulum* gave a very simple diagram, the motion being in two mutually rectangular directions, namely, *E—W* and *N—S*.
Max. $2a = 0.3\text{mm}$.

Hongo.

Duration = 40s. The motion consisted of small gentle horizontal shakings, the vertical motion being very slight.

Max. $2a = 0.2\text{mm}$, $T_o = 0.7\text{s}$; $V = 0.9 \text{ mm/s}$, $A = 8.1 \text{ mm/s}^2$

Eqke No. 30. Dec. 17, 1887 ; 6.18.22 a.m.

A tremor observed at the *Cent. Met. Observatory*.

Eqke No. 31. Dec. 17, 1887 ; 11.41.14 p.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 10s.

Direction. *E—W*.

Max. H. M. 0.25s (period = 0.6s)

Character. Gentle.

Hitotsubashi.

Duration = 85s.

Max. $2a = 0.2\text{mm}$, $T_o = 0.8\text{s}$; $V = 0.8 \text{ mm/s}$, $A = 6.2 \text{ mm/s}^2$

The average period was 0.71s.

The *Duplex pendulum* *Hitotsubashi* at indicated movements chiefly in the *ESE—WNW* direction.

Hongo.

Horizontal motion. Duration = 45s.

Max. $2a = 0.2\text{mm}$, $T_o = 0.4\text{s}$; $V = 1.6\text{ mm/s}$, $A = 24.6\text{ mm/s}^2$

The average period was 0.59s.

Vertical motion. Duration = 10s. The motion was very small, the average period being 0.03s.

Eqke No. 32. Dec. 19, 1887; 6.0.12 p.m.

A tremor observed at the *Cent. Met. Observatory.*

Eqke No. 33. Dec. 21, 1887; 2.5.55 p.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 15s.

Max. H. M. Very small.

Eqke No. 34. Dec. 24, 1887; 4.9.41 a.m.

A tremor observed at the *Cent. Met. Observatory.*

Eqke No. 35. Dec. 24, 1887; 7.51.38 a.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 60s.

Direction. *SW—NE.*

Max. H.M. 0.2mm (period = 2s).

Character. Gentle.

Hitotsubashi.

Duration = 120s.

Max. $2a = 0.2\text{mm}$, $T_o = 0.8\text{s}$; $V = 0.8\text{ mm/s}$, $A = 6.2\text{ mm/s}^2$

The average period was 0.78

Eqke No. 36. Dec. 27, 1887;—

A very small earthquake, not observed at the *Cent. Met. Observatory.*

Hitotsubashi.

Horizontal motion. Duration = 83s. The motion was slightly larger in the *EW* than in the *NS* component.

Max. $2a = 0.1\text{mm}$, $T_0 = 0.7\text{s}$; $V = 0.5\text{ mm/s}$, $A = 4\text{ mm/s}^2$

There was no vertical motion.

According to the *Duplex Pendulum* diagram at Hitotsubashi, there were two principal directions of motion, namely, *E-W* and *N-S*, the motion in the former direction being greater than that in the latter. This may indicate that the earthquake origin was towards *E* or *W* of Tokyo and gave rise to the normal and transverse sets of waves.

Eqke No. 37. Dec. 31, 1887; 1.24.45 a.m.

A small shock observed only at the *Cent. Met. Observatory*.

Eqke No. 38. Jan. 1, 1888; 3.31.38 p.m.

Hitotsubashi.

Duration = 100s. The motion, which consisted of perfectly regular vibrations, was much greater in the *NS* than in the *EW* component, there being no vertical motion. The earthquake began very gently, soon reached the maximum, and then gradually decreased.

Max. $2a = 0.28\text{ mm}$ in the *EW* and 0.2 mm in the *NS* component; $T = 0.9\text{s}$; $V = 1.0\text{ mm/s}$, $A = 6.8\text{ mm/s}^2$

The average period of vibration (*NS* component) was as follows:—

25 vibrations during the first 22.5s gave an aver. period of 0.90s;

24 „ „ „ next 20.4s „ „ „ „ „ 0.85s;

46 „ „ „ 38.2s in the very end part of the earthquake gave an aver. period of 0.83s.

Thus the period remained very nearly constant, becoming, however, slightly shorter towards the end.

Eqke No. 39. Jan. 11, 1888; 8.50.36 a.m.

This was an earthquake of moderate intensity.

Observation at the *Cent. Met. Observatory*.

Duration = 60s.

Direction. *ESE-WNW*.
 Max. H.M. 0.4mm (period = 1.8s).
 Max. V.M. ———
 Character. Gentle.

Hitotsubashi.

Duration = 120s. The motion was much greater in the *NS* than in the *EW* direction, there being no vertical component. The following maximum motion occurred at about 2s after the commencement:—

Max. $2a = 0.6\text{mm}$, $T_0 = 0.79\text{s}$; $V = 2.4\text{ mm/s}$, $A = 19\text{ mm/s}^2$

Each horizontal component motion consisted of a series of very regular simple harmonic vibrations. In the *NS* component, the amplitude was great at the commencement, then became small, and then again increased, etc., thus presenting a series of maximum and minimum groups. The maximum displacements occurred at 2s, 7s, 26s and 43s respectively after the commencement. The relation between the $2a$ and T of vibration in the *NS* component is given in the following table.

HITOTSUBASHI : NS COMPONENT.

2a (mm)	T (sec.)	2a (mm)	T (sec.)
0.5	0.91	0.3	0.74
0.5	0.89	0.3	0.78
0.45 } 0.45 (mean)	0.87 } 0.89 (mean)	0.3	0.76
0.45	0.87	0.3	0.79
0.43	0.91	0.28	0.69
0.40	0.87	0.28	0.87
0.40	0.87	0.25 } 0.27 (mean)	0.74 } 0.78 (mean)
0.38	0.87	0.25	0.71
0.38	0.87	0.25	0.74
0.38	0.84	0.25	0.81
0.38	0.80	0.25	0.87
0.38 } 0.38 (mean)	0.80 } 0.88 (mean)	0.25	0.82
0.38	0.93	0.25	0.82
0.38	0.88	0.2	0.74
0.38	0.78	0.2	0.80
0.38	0.82	0.2 } 0.19 (mean)	0.78 } 0.77 (mean)
0.35	0.95	0.2	0.78
0.35	0.99	0.2	0.81
0.35	0.99	0.15	0.72

The measurement in the above table was taken from the earlier portion of the earthquake. Towards the very end, the mean period was 0.78s.

The above table indicates a slight variation of the period with amplitude. The period, however, remained on the whole constant. Thus, arranging the 37 vibrations given in the table in order of time, the first 19 give an average period of 0.82s, while the remaining 18 give an average period of 0.84s.

Hongo.

Horizontal motion. Duration = 65s. As at Hitotsubashi, the motion was much greater in the *NS* than in the *EW* component.

Max. $2a = 0.32\text{mm}$, $T_o = 0.48\text{s}$; $V = 2.1\text{ mm/s}$, $A = 28\text{ mm/s}^2$

In the *NS* component, which was greatest at the commencement and indicated a series of alternations of maximum and minimum groups, the motion consisted of regular simple vibrations, whose average period, deduced from 51 vibrations, was 0.43s. In the *EW* component, the motion, which was at first irregular, became afterwards regular and had an average period of 0.77s.

The ripples which existed in the earlier part of the *EW* component, had an average period of 0.17s.

Vertical motion. Duration = 22s.

The motion, which was most active at the commencement and thence gradually decreased, consisted of very small regular vibrations, whose average period, deduced from 27 vibrations, was 0.17s.

Max. $2a = 0.06\text{mm}$, $T_o = 0.19\text{s}$; $V = 1\text{ mm/s}$, $A = 33\text{ mm/s}^2$.

It will be observed that, in this case, the period of vibration of the vertical motion was equal to that of the ripples in the *EW* component.

Eqke No. 40. Jan. 13, 1888 ;—

Hitotsubashi.

This was a very small earthquake, chiefly in the *EW* component.

The average period, deduced from 45 vibrations in the *EW* component, was 0.64s.

Eqke No. 41. Jan. 14, 1888 ; 5.31.55 p.m.

Observation at the *Cent. Met. Observatory* : — —

Duration. 15s.

Direction. *E-W*.

Max. H.M. Small.

Max. V.M. Very small.

Character. Quick.

Eqke No. 42. Jan. 27, 1888 ; 10.5.33 a.m.

Observation at the *Cent. Met. Observatory* : —

Duration. 10s.

Direction. *N-S*.

Max. H.M. Small.

Character. Gentle.

Hitotsubashi.

Duration = 60s. The motion was almost exclusively in the *EW* direction, there being no vertical component. The diagram consists of regular simple harmonic curves.

Max. $2a = 0.38\text{mm}$, $T_0 = 0.91\text{s}$; $V = 1.3\text{ mm/s}$, $A = 9.1\text{ mm/s}^2$

The average period, deduced from 11 vibrations in the *EW* component, was 0.89s.

The Duplex Pendulum at Hitotsubashi recorded movements almost entirely in the *EW* direction.

Eqke No. 43. Feb. 2, 1888 ; 1.15.15 p.m.

This was the first and strongest of the four earthquakes which occurred on the afternoon of the 2nd of February.

Observation at the *Cent. Met. Observatory* : —

Duration. 228s.

Direction. *ESE—WNW*.

Max. H.M. 13mm (period = 3.7s ?)

Max. V.M. 0.5mm.

Character. Quick.

Remark. The earthquake began with tremors in the *EW* direc-

tion, the tremors in the *NS* component occurring 11s later on. At 23rd second, large movements began to appear in the *EW* component, accompanied by active vertical movements, while in the *NS* component the motion became large first at the 33rd second. The maximum vibration occurred at the 42nd second, the motion remaining still active for the next 63s.

Area of disturbance. The earthquake, whose total land area of disturbance covered 3420 sq. *ri*, was felt in the following 16 provinces: Hitachi, Shimosa, Kazusa, Awa, Musashi, Sagami, Kai (eastern part), Suruga (north-eastern portion), Shinano (eastern portion), Kozuke, Shimotsuke, Echigo (eastern portion), Iwashiro, Iwaki, Uzen (south-eastern portion) and Rikuzen (southern part).

The area of *strong* motion was 450 sq. *ri* and included the provinces of Hitachi (southern part), Shimosa, Kazusa (northern portion) and Musashi (eastern portion). The motion was felt very strongly in the Kajima District of Hitachi, where the direction was *SE-NW* or *S-N*, and where liquids were thrown out. In Kaijō District of Shimosa the earthquake was less severe than that of Sept. 5, 1887. In Tokyo, some pendulum clocks were stopped. The 2nd earthquake, observed in Tokyo at 2.23.46 p.m., was less strong and was felt in the eight provinces of Hitachi, Kazusa, Shimosa, Musashi, Kozuke, Shimotsuke, Iwaki and Iwashiro. The 3rd earthquake, observed in Tokyo at 3.0.14 p.m., was in some places felt *weakly*; the area of disturbance including the five provinces of Hitachi, Kazusa, Shimosa, Musashi and Shimotsuke. The 4th earthquake, observed in Tokyo at 3.41.27 p.m., was felt *strongly* in the southern part of Hitachi and the eastern part of Shimosa; the area of disturbance including the following 12 provinces: Hitachi, Kazusa, Awa, Musashi, Shimosa, Sagami, Shimotsuke, Kozuke, Iwaki, Iwashiro, Uzen and Rikuzen.

Hongo.

Horizontal motion.

Duration = 130s (*EW* component);

„ = 110s (*NS* „).

The preliminary tremor lasted 3.6s in the *EW* and 7.2s in the *NS* component.

The motion, which was larger in the *EW* than in the *NS* component, consisted in the latter of moderate vibrations, which were at first irregular but afterwards became regular and nearly constant in amplitude, there being no very prominent wave. In the *EW* component, there were some large movements, the motion being more complicated than in the other component.

The maxima did not occur simultaneously in the two components, the *EW* maximum happening earlier than the *NS* one. The times of occurrence of these displacements were as follows :—

EW COMPONENT.

{	1st	Max.	occurred	3.6s	after the commencement,	. . . .	(1)
	2nd	,,	,,	10.s	,,	,,	. . . . (2)
	3rd	,,	,,	17.s	,,	,,	. . . . (3)
	4th	,,	,,	25.s	,,	,,	. . . . (4)

NS COMPONENT.

{	1st	Max.	occurred	7.2s	after the commencement,	. . . .	(1')
	2nd	,,	,,	17.s	,,	,,	. . . . (2')
	3rd	,,	,,	24.s	,,	,,	. . . . (3')
	4th	,,	,,	31.s	,,	,,	. . . . (4')

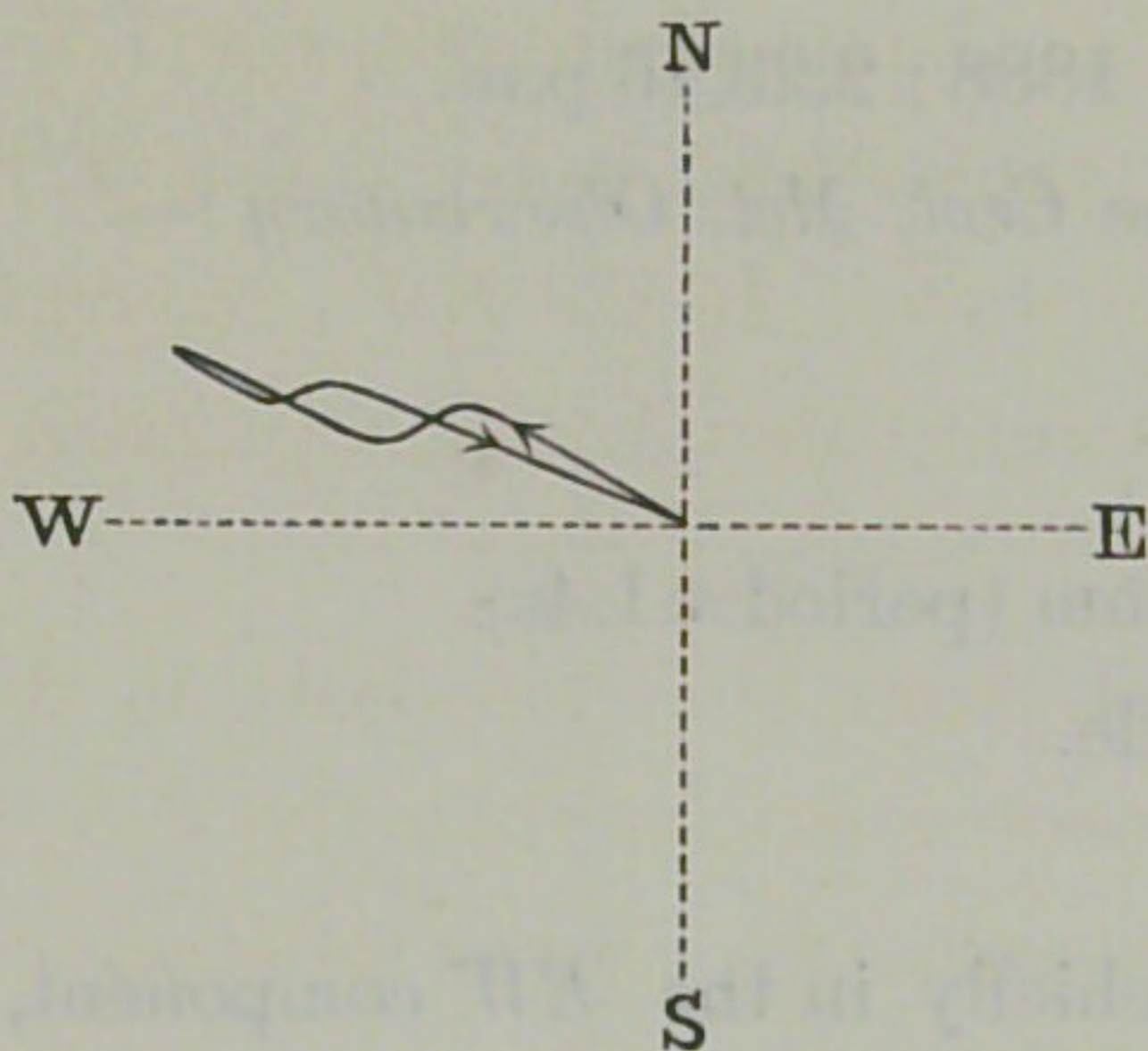
If the displacements (1) to (4) in the *EW* component be regarded as corresponding respectively to the displacements (1') . . . (4') in the *NS*, we may conclude that the waves of the former component reached in the mean about 6s earlier than those of the latter. Now, as the origin of the earthquake was situated due east of Tokyo, the *EW* component would correspond to the normal wave and the *NS* component to the transverse wave.

The absolutely maximum motion, which occurred about 17s after the commencement was the following :—

$$\text{Max. } 2a = 2.0\text{mm, Direction } W 20^\circ N, T_o = 1.3\text{s; } V = 4.8\text{mm/s,}$$

$$A = 23\text{mm/s}^2.$$

Then there followed a counter displacement of nearly equal amplitude towards the opposite direction. (See the annexed diagram.)



The periods of vibration in the two components are given next.—

In the *EW* component the average period of the ripples, which existed in the earlier part, was 0.16s; in the *NS* component the corresponding period was 0.13s. In the former component, the ripples lasted about 20s. The average period of vibrations in the end portion was 0.86s in the *EW* and 0.47s in the *NS* component.

Vertical motion. Duration = 34s.

The motion was nearly uniform, there being no preliminary tremor. The max. $2a$ was the following:—

$$\text{Max. } 2a = 0.18\text{mm}, T_0 = 0.43\text{s}; V = 1.3\text{mm/s}, A = 19\text{mm/s}^2$$

This occurred 11s after the commencement, there being a second maximum 5s later on. These movements did not occur simultaneously with the maxima in the *EW* direction the period being also widely different in these two components, which seemed to be totally independent of each other. This fact shows that the vertical motion was not, in this case, the vertical component of the normal wave.

The average period deduced from 30 vibrations was 0.29s.

The Duplex Pendulum at Hongo indicated motion chiefly in the directions *ESE-WNW* and *NEN-SWS*, the former component being the predominating one.

Hitotsubashi.

The Duplex Pendulum indicated the max. 2a of about 5.0mm, the principal directions being *E-W* and *NEN-SWS*.

Eqke No. 44. Feb. 2, 1888 ; 2.23.46 p.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 109s.

Direction. *E-W*.

Max. H. M. 0.7mm (period = 1.4s).

Character. Gentle.

Hongo.

The motion was chiefly in the *EW* component, the max. 2a being 0.2mm. There was no vertical motion.

Eqke No. 45. Feb. 2, 1888 ; 3.0.14 p.m.

A tremor, observed only at the *Cent. Met. Observatory*.

Eqke No. 46. Feb. 2, 1888 ; 3.41.27 p.m.

Observation at the *Cent. Met. Observatory*.

Duration. 45s.

Direction. *WSW-ENE*.

Max. H. M. 3.8mm (period = 2.4s).

Max. V. M. ———

Character. Gentle.

Remark. The earthquake, which began with small movements, became active the at 42nds there being 12 principal vibrations during the next 14s. The motion decreased gradually from the 74th second.

Hongo.

The motion was moderately large and sharp, the character being on the whole similar to that of eqke No. 43.

Horizontal motion. The amplitude was nearly equal in the two components.

Duration = 115s (*EW* component) ;

„ = 85s (*NS* „).

The earlier part of the *EW* component consisted entirely of ripples, while the corresponding portion of the *NS* component consisted of slow large vibrations superposed with ripples; so that the ground moved during the first 15 seconds sensibly in the *NS* direction and thereafter more in the *EW* direction. The average period of the ripples was 0.19s in the *EW* and 0.16s in the *NS* component.

Max. $2a = 0.5\text{mm}$, $T_o = 0.57$; $V = 2.8\text{mm/s}$, $A = 31\text{mm/s}^2$

After the disappearance of the superposed ripples the vibrations in each component became regular, the average period being 0.81s in the *EW* and 0.48s in the *NS* component.

Vertical motion. Duration = 26s.

The motion consisted of very small vibrations, whose average period was 0.23s.

Max. $2a = 0.06\text{mm}$, $T_o = 0.4\text{s}$; $V = 0.5\text{mm/s}$, $A = 8\text{mm/s}^2$

Duplex Pendulum. The motion was chiefly in the *EW* and *NS* directions.

Eqke No. 47. Feb. 3, 1888; 2.31.56 p.m.

This was a very small tremor, recorded by the Duplex Pendulum at Hongo.

Eqke No. 48. Feb. 5, 1888; 0.50.56 a.m.

This was a very extensive earthquake, whose origin was near the Tsugaru strait; Tōkyō being on the edge of the shaken area.

Observation at the *Cent. Met. Observatory* :—

Duration. 60s.

Direction. *SW-NE*.

Max. H. M. 1.6mm (period = 2.1s).

Character. Gentle.

Area of disturbance. The land area of disturbance was 9000 sq. *ri* and extended from Hokkaido on the north down to Kazusa and Musashi on the south, including the following 23 provinces :—Oshima, Shiribeshi,

Iburi, Hidaka, Tokachi, Kushiro, Nemuro, Ishikari, Kitami (south eastern part), Teshiwo (southern portion), Mutsu, Rikuchu, Ugo, Uzen, Rikuzen, Iwaki, Hitachi, Shimosa, Iwashiro, (eastern part), Shimotsuke, Kotsuke (south-eastern portion), Musashi (eastern portion), Kazusa (northern part). The shock was felt *strong* in Mutsu (northeastern part), Oshima (eastern portion), Iburi (south-eastern portion), Hidaka (southern part) and Tokachi (south-western portion). No severe damage, however, was produced.

Hitotsubashi.

Duration = 120s. There was no vertical motion.

The motion began gently with extremely small undulations, whose period was, however, not shorter than that in the principal portion. In the *NS* component, the chief motion appeared about 40s after the commencement.

Max. $2a = 1.0\text{mm}$, $T_0 = 0.57\text{s}$; $V = 5.5\text{mm/s}$, $A = 60\text{mm/s}^2$

The average period, deduced from 68 vibrations in the *NS* component, was 0.45s.

The Duplex Pendulum indicated motion chiefly in the *NS* and *EW* directions.

Hongo.

The amplitude of motion was nearly equal in the two horizontal components. The period of vibration was as follows: —

EW component Aver. period = 0.84s (deduced from 19 vibrations);

NS component Aver. period = 0.47s (deduced from 23 vibrations).

Eyke No. 49. Feb. 10, 1888; 3.26.55 p.m.

Observation at the *Cent. Met. Observatory*:—

Duration. 10s.

Direction. *NE-SW*.

Max. H. M. Small.

Max. V. M. —

Character. Quick.
Hitotsubashi.

Duration=25s. The motion consisted of very small slow undulations which were nearly equal in the two horizontal components. No vertical motion.

$$\text{Max. } 2a = 0.25\text{mm}, T_o = 0.6\text{s}; V = 1.3\text{mm/s}, A = 13\text{mm/s}^2$$

The period of vibration was as follows :—

EW component Aver. period=0.78s (deduced from
 3 vibrations);

NS component Aver. period=0.7s (deduced from
 16 vibrations).

The Duplex Pendulum gave a very simple diagram, the motion being chiefly in the *NS* direction and to a slight amount in the *EW* direction.

Eqke No. 50. Feb. 10, 1888; 36.8.7 p.m.

Observation at the *Cent. Met. Observatory.*

Duration. 12s

Direction. *E-W.*

Max. H.M. Very small.

Hitotsubashi.

Duration=30s. The motion was chiefly in the *NS* direction, there being no vertical component.

$$\text{Max. } 2a = 0.25\text{ mm}, T_o = 0.62\text{s}; V = 1.3\text{mm/s}, A = 12.9\text{mm/s}^2$$

The movements were very small and constant in period, the average value, deduced from 21 vibrations in the *NS* component, was 0.70s.

The Duplex Pendulum at Hitotsubashi gave a very simple diagram, which consisted of only a few movements in the *NS* direction.

Hongo.

Duration=35s. The motion was very small, there being no vertical component.

$$\text{Max. } 2a = 0.15\text{ mm}, T_o = 0.5\text{s}; V = 0.94\text{ mm/s}, A = 12\text{ mm/s}^2$$

The Duplex Pendulum at Hongo indicated movements chiefly in the *EW* direction.

Eqke No. 51. Feb. 11, 1888 ; 3.38.56 p.m.

Recorded at the *Cent. Met. Observatory* as a *slight* shock.

Hongo.

Duration = 40s. The motion, which was very small, occurred equally in the two horizontal components.

Max. $2a = 0.1$ mm, $T_o = 0.5$ s ; $V = 0.6$ mm/s, $A = 7.9$ mm/s.²

Eqke No 52. Feb. 13, 1888 ; 11.33.44 a.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 25s.

Direction. *N-S*.

Max. H.M. Small.

Character. Gentle.

Hitotsubashi.

Duration = 40s. The motion consisted of very small vibrations, whose average period, deduced from 12 vibrations in the *NS* component, was 0.52s.

Max. $2a = 0.1$ mm, $T_o = 0.45$ s ; $V = 0.7$ mm/s, $A = 10$ mm/s.²

The Duplex Pendulum at Hitotsubashi indicated movements chiefly in the *NS* direction.

Hongo.

The diagram indicated very small movements.

Eqke No. 53. Feb. 15, 1888 ; 3.43.38 p.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 30s.

Direction. *E-W*.

Max. H.M. Very small.

Character. Gentle.

Hitotsubashi and Hongo. Motion was very small.

Eqke No. 54. Feb. 17, 1888 ; 0.16.17 p.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 50s.

Direction. *E-W*.

Max. H.M. Very small.

Character. Gentle.

This earthquake was not felt at *Hongo*.

Eqke No. 55. Feb. 18, 1888 ; 6.13.45 p.m.

Observation at the *Cent. Met. Observatory* :—

Direction. *E-W*.

Max. H.M. Very small.

Character. Gentle.

Eqke No. 56. Feb. 22, 1888 ; 10.24.43 a.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 90s.

Direction. *N-S*.

Max. H.M. 0.7mm (period = 3.2s)

Character. Gentle.

Hitotsubashi.

Duration = 120s. This was a moderate earthquake, the motion being at first somewhat greater in the *NS* than in the *EW* component.

Max. $2a = 0.45$ mm, $T_o = 0.78$ s ; $V = 1.8$ mm/s, $A = 14$ mm/s.²

The average period in the *NS* component was 0.67s.

Hongo.

Duration = 100s. The motion was chiefly in the *NS* direction, there being no vertical motion.

Max. $2a = 0.24$ mm, $T_o = 0.79$ s ; $V = 0.95$ mm/s, $A = 7.5$ mm/s.²

The average period in the *NS* component was 0.74s.

Eqke No. 57. Feb. 22, 1888 ; 11.10.50 p.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 10s.
 Direction. N-S.
 Max. H.M. Very small.
 Character. Gentle.

Eqke No. 58. Feb. 24, 1888; 2.7.6 a.m.

Observation at the *Cent. Met. Observatory* :—

Duration. —
 Direction. E-W.
 Max. H.M. Very small.
 Character. Gentle.

Hitotsubashi.

Duration = 120s. The motion, which consisted of regular vibrations of constant period, was almost entirely in the *EW* direction, there being no vertical component.

Max. $2a = 0.4$ mm, $T_o = 0.84$ s; $V = 1.5$ mm/s, $A = 11$ mm/s.²

The average period, deduced from 37 vibrations in the *EW* component, was 0.85s.

Hongo.

Duration = 25s. This was a very small earthquake, the motion being almost entirely in the *NS* component. There was no vertical motion.

Max. $2a = 0.12$ mm, $T_o = 0.52$ s; $V = 0.73$ mm/s, $A = 9$ mm/s.²

The average period, deduced from 30 vibrations in the *NS* component, was 0.46s.

Eqke No. 59. March 1, 1888; 3.30.15 p.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 88s.
 Direction. WSW—ENE.
 Max. H.M. Small.
 Character. Gentle.

Hitotsubashi.

Duration = 100s. The motion, which was very small, was chiefly in the *EW* component, there being no vertical component.

Max. $2a = 0.4$ mm, $T_0 = 0.7$ s; $V = 1.8$ mm/s, $A = 16$ mm/s²

The average period, deduced from 25 vibrations in the *EW* component, was 0.71s.

Eqke No. 60. March 1, 1888; 9.54.12 p.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 30s.

Direction. *N-S*.

Max. H.M. Small.

Max. V. M. —

Character. Quick.

Hongo.

Horizontal motion. Duration = 16s.

The motion consisted of a series of extremely small quick vibrations, and was almost entirely in the *EW* component, the average period being 0.23s.

Max. $2a = 0.1$ mm.

Vertical motion. The duration was very short.

The motion was very small, the average period being 0.17s.

Eqke No. 61. March 9, 1888; 4.54.16 a.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 25s.

Direction. *NWN-SES*.

Max. H.M. 0.4 mm (period = 0.2s).

Max. V.M. —

Character. Quick.

Remark. For the first 3s, the vibrations were quick. Then followed suddenly the most active part of the motion, which lasted 2s. Thereafter the vibrations became again abruptly small.

Hitotsubashi.

On this occasion, the motion at *Hitotsubashi* was smaller than that at *Hongo*.

Horizontal motion. Duration (obscured). The motion was chiefly in the *EW* component.

Max. $2a = 0.32$ mm, $T_o = 0.86$ s; $V = 1.2$ mm/s, $A = 9$ mm/s.²

Vertical motion. The motion was very slight.

Hongo.

Horizontal motion. Duration = 30s.

The motion occurred equally in the two horizontal components and consisted of very quick vibrations. The *principal portion* lasted only for a few seconds, the subsequent motion being much smaller.

Max. $2a = 0.32$ mm, $T_o = 0.3$ s; $V = 3.4$ mm/s, $A = 72$ mm/s.²

In the *EW* component, the average period was at first 0.18s, but towards the end 0.37s.

In the *NS* component, the period remained constant, the average value being 0.19s.

Vertical motion. Duration = 12s. The vertical motion existed in a comparatively large amount. The following maximum motion occurred at the commencement.

Max. $2a = 0.07$ mm, $T_o = 0.26$ s; $V = 0.9$ mm/s, $A = 2.1$ mm/s.²

The average period of vibration was at first 0.12s and towards the end 0.16s.

In this case, there was apparently parallelism between the horizontal and vertical components, both being maximum at the commencement and also of nearly the same period.

Eqke No. 62. March 16, 1888; 6.43.0 a.m.

Hitotsubashi

Horizontal motion. Duration = 100s. The motion, which was almost entirely in the *EW* component, began very gently and remained nearly constant in amplitude through a considerable interval of time.

Max. $2a = 0.4$ mm, $T_o = 0.74$ s; $V = 1.7$ mm/s, $A = 15$ mm/s.²

The period remained constant, the average value, deduced from 38

vibrations in the *EW* component, being 0.85s.

Vertical motion. There were only very slight traces of vertical motion.

Hongo.

Horizontal motion. Duration = 70s. The motion, which was very small, occurred equally in the two horizontal components.

Vertical motion. The motion was very slight.

Eqke No. 63. March 17, 1888 ; 7.55.36 p.m.

A tremor, observed only at the *Cent. Met. Observatory.*

Eqke No. 64. April 1, 1888 ; 6.17.8 a.m.

Observation at the *Cent. Met. Observatory* :—

Duration. —

Max. H.M. Very small.

Character. Gentle.

Eqke No. 65. April 5, 1888 ; 2.30.29 p.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 120s.

Direction. *SE-NW.*

Max. H.M. 1.2 mm (period = 0.7s).

Max. V.M. 0.5 mm (period = 0.3s).

Character. Quick.

Remark. The earthquake began with horizontal and vertical tremors which lasted for 10s. Then the motion became suddenly great, remaining active for the next 30s. This earthquake, notwithstanding the smallness of amplitude, was felt violently, probably because it was accompanied by quick period vertical vibrations throughout the whole duration.

Area of disturbance. The total land area of disturbance was 4060 sq. *ri* and extended over the following 16 provinces :— Hitachi, Shimosa,

Shimotsuke, Kazusa, Musashi, Awa, Sagami Kōtsuke, Izu, Kai, Iwaki, Iwashiro (southern part), Rikuzen (southern portion), Echigo (southern portion), Shinano (eastern part), Suruga (eastern part). The motion was *strong* within an area of 690 sq. *ri* which included Hitachi (central portion), Shimosa (north-western part), Musashi (north-eastern part), Kotsuke (eastern portion), Shimotsuke (southern part). The shock was felt very violently in the Makabe District of Hitachi, where workmen on house roofs had difficulty in supporting themselves on account of sudden powerful vertical movements. Again, in the Kawachi District of Shimotsuke the motion was very violent, and *shoji* and other sliding doors were almost thrown down. The directions of motion in the strongly shaken area were mostly *SE-NW* or *S-N*. No severe damage was produced.

Hitotsubashi.

Horizontal motion. Duration = 150s.

The motion at *Hitotsubashi*, which was somewhat greater in the *EW* than in the *NS* component, consisted of regular vibrations not so much superposed with ripples as at *Hongo*. The *NS* component began with preliminary tremor, which lasted for 3s. The *EW* component, however, was already well pronounced at the commencement, so that the ground moved at first chiefly in the *EW* direction.

The motion consisted of a great number of vibrations whose amplitude remained nearly equal for a considerable interval of time, and whose period remained constant till the very end. The following maximum vibration, nearly in the *EW* direction, took place 18 seconds after the commencement:—

$$\text{Max. } 2a = 2.0 \text{ mm, } T_0 = 0.77 \text{ s; } V = 8.2 \text{ mm/s, } A = 67 \text{ mm/s}^2$$

The relation between the $2a$ and T of the horizontal vibrations is given in the next table:—

HITOTSUBASHI; HORIZONTAL MOTION.

2a (mm)	T (sec.)	2a (mm)	T (sec.)
2.0	0.77	1.0	0.80
2.0	0.77		
1.9	0.77		
1.8	0.92		
1.8	0.84		
1.8	0.71		
1.6	0.84	0.95	0.75
1.5	0.70		
1.5	0.84		
1.4	0.69		
1.4	0.84	0.93	0.73
1.3	0.73		
1.25	0.84	0.9	0.73
1.25	0.80		
1.2	0.70		
1.2	0.71		
1.15	0.69		
1.15	0.65		
1.1	0.69	0.75	0.84
1.1	0.77		
1.05	0.92		
1.05	0.72		
1.05	0.84		

The measurement given in the above table has been taken from the first 50 s of the diagram. Towards the very end, the average period, deduced from 10 vibrations, was 0.70s.

The relation between the 2a and *T* given above relates to the resultant vibrations, that is to say, the 2a was obtained in each case by compounding the corresponding displacements in the two directions. If we take the two components separately, the result is as follows:--

In the *EW* component, the average period, deduced from 150 vibrations during the first two minutes was 0.75 s, while that deduced from 14 vibrations at the very end was 0.77s. In the *NS* component, the corresponding average periods, deduced respectively from 83 and 8 vibrations, were 0.77s and 0.80s. These values are nearly the same as those given in the above table, which give a mean period of 0.76s.

Vertical motion. Duration = 50s.

The vertical motion began with preliminary tremor whose duration was nearly equal to that in the *NS* component, the motion being well pronounced during the first 20s. The following maximum vibration occurred about 11s after the commencement, simultaneous with a large horizontal displacement in the *EW* direction :--

$$\text{Max. } 2a = 0.6 \text{ mm, } T_0 = 0.65\text{s; } V = 2.9 \text{ mm/s, } A = 28 \text{ mm/s}^2$$

The relation between the $2a$ and T of the vertical motion was as follows.

HITOTSUBASHI : VERTICAL MOTION.

2a (mm)	T (sec.)	2a (mm)	T (sec.)
0.6	0.65	0.21	0.51
0.5	0.6	0.21	0.57
0.36	0.43	0.21	0.60
0.33	0.44	0.14	0.48
0.3	0.46	0.14	0.51
0.3	0.57	0.14	0.46
0.26	0.43	very small	0.34
0.21	0.40	”	0.37
0.21	0.43		
0.21	0.51		

Thus in this earthquake the period of the vertical vibrations, which remained on the whole constant, was much slower than is usually the case.

Hongo.

Horizontal motion. Duration = 110s.

The motion began with preliminary tremor of a very short duration. There was no single prominent maximum, but the earthquake consisted at first essentially of quick sharp vibrations or ripples of an average period of 0.2s superposed on slow undulations ; the ripples subsequently disappearing. The motion was somewhat larger in the *NS* than in the *EW* component.

$$\text{Max. } 2a = 1.4 \text{ mm, } T_0 = 0.71\text{s, } \textit{Direction} \text{ nearly } \textit{NEN}, \text{ } V = 6.2 \text{ mm/s, } A = 55 \text{ mm/s}^2$$

The two largest ripples were as follows:—

(1) $2a=0.54$ mm, $T=0.2$ s; $V=8.5$ mm/s, $A=270$ mm/s².

(2) $2a=0.74$ mm, $T=0.24$ s; $V=9.7$ „ „, $A=250$ „ „.

The ripples lasted for 25s.

The average period of the undulations, which became regular after the disappearance of the ripples, was as follows:—

EW component 0.57s (deduced from 50 vibrations);

NS „ „ 0.78s („ „ „ 49 „ „ „).

I may here note that the earthquake of March 9th 1888 was moderately severe, but the minute ripples, which constituted its commencement and principal portion, were far smaller than those occurring in the earlier portion of the present earthquake. It may, therefore, be supposed that the severity of shocks at *Hongo* is largely due to ripples.

Vertical motion. Duration=25s.

The vertical motion, which was active from the commencement, consisted of nearly equal minute vibrations whose period was approximately constant and had an average value of about 0.2s. There was no single prominent wave.

Max. $2a=0.14$ mm, $T_o=0.24$ s; $V=1.8$ mm/s, $A=48$ mm/s².

The origin of the earthquake was nearly due north of Tokyo. From the analysis of the diagrams at *Hongo* and *Hitotsubashi* given above it seems that the vibrations were not distinctly divided into the *normal* and the *transverse* waves.

Eqke No. 66. April 8, 1888; 2.22.32 p.m.

A tremor observed only at the *Cent. Met. Observatory*.

Eqke No. 67. April 7, 1888;—

Hitotsubashi.

Duration=40s. The motion which consisted of perfectly regular vibrations was chiefly in the *EW* direction, there being no vertical component.

Max. $2a=0.38$ mm, $T_o=0.83$ s; $V=1.4$ mm/s, $A=10$ mm/s².

The average period deduced from 25 vibrations in the *EW* component was 0.78s.

Hitotsubashi.

The average period, deduced from 20 vibrations in the *EW* component, was 0.79s.

Eqke No. 68. April 16, 1888 : 11.6.43 p.m.

A tremor observed only at the *Cent. Met. Observatory.*

Eqke No. 69. April 29, 1888 ; 10.0.33 a.m.

Observation at the *Cent. Met. Observatory :*

Duration = 8m.

Direction. *SE-NW.*

Max. H.M. 5.6mm (period = 0.8s).

Max. V.M. 1.5mm (period = 0.6s).

Character. Quick.

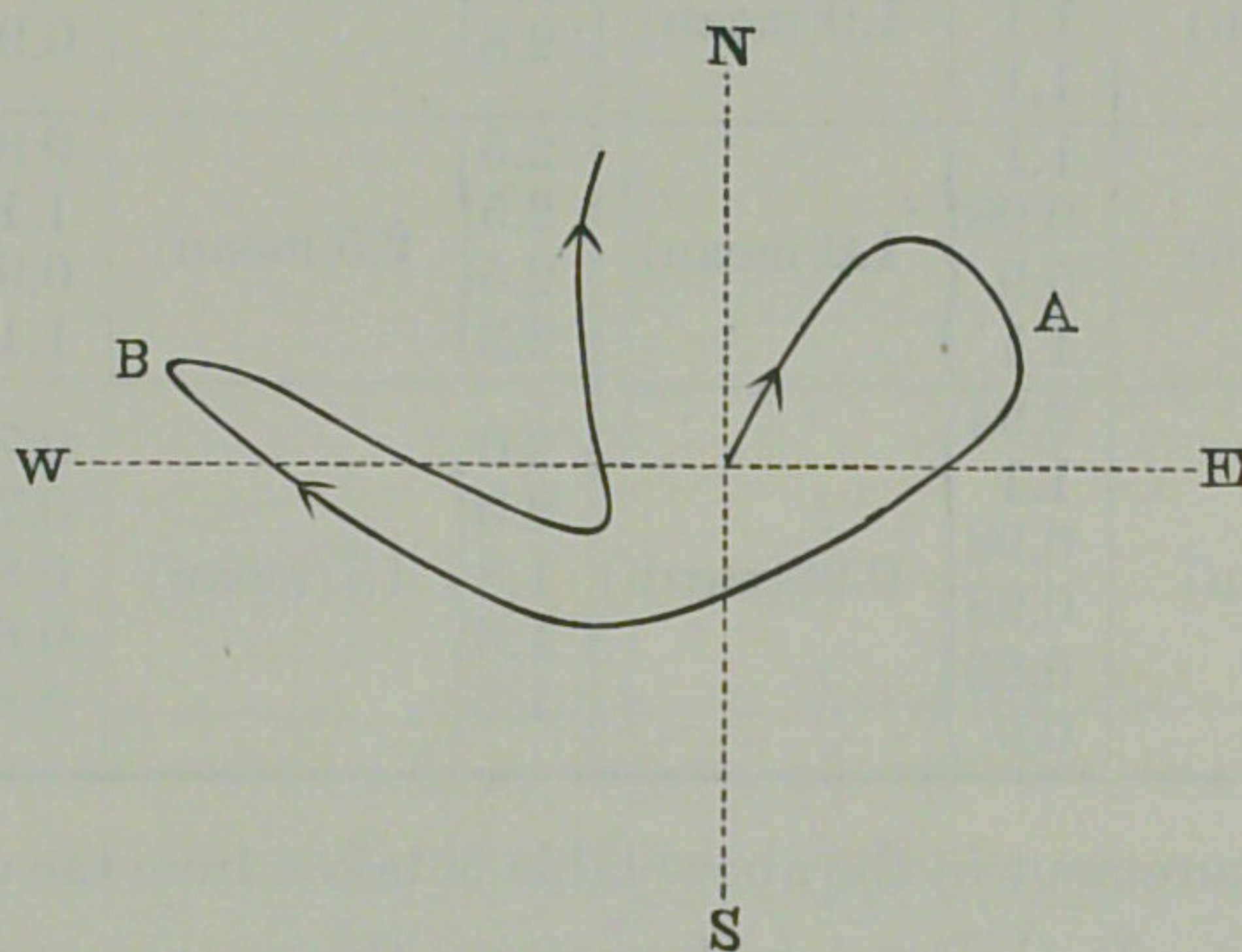
Remark. The earthquake began with horizontal and vertical tremors, which lasted for 12s, when the maximum horizontal motion suddenly took place. The maximum vertical motion occurred at the 17th second, the total duration being 1m 14s. The horizontal motion remained more or less active for the first 3 minutes.

Area of disturbance. The total land area of disturbance, which was unusually large, was 5080 sq. *ri* and extended from the Pacific to the coast of Echigo, including the following 20 provinces:—Musashi, Sagami, Izu, Suruga, Totomi, Kai, Kotsuke, Shimotsuke, Hitachi, Kazusa, Awa, Shimoso, Iwaki, Iwashiro, Shinano, Rikuzen(southern portion), Uzen (southern portion), Echigo (central part), Mikawa (eastern part). The area of *strong motion* was 1930 sq. *ri* and included the 12 provinces of Musashi, Sagami, Izu, Suruga(eastern part), Kai(eastern part), Shinano (eastern portion), Kozuke (south-eastern part), Shimotsuke (southern part), Hitachi (southern part), Shimoso (western part), Kazusa (western portion), Awa (western part). Within this area some slight damage was produced, such as cracks and subsidence of embankments(Nasu District,

Shimotsuke); cracks of walls(Utsunomiya and Shimo-tsuga District, Shimotsuke); overturning of furnitures(Tokyo and Kita-Saitama District, Musashi); overflowing of liquids (Kuraki District, Musashi; Minami-Saku District, Shinano; Izu; Haga District, Shimotsuke); stopping of pendulum clocks (Izu; Minami-Saku District, Shinano.)

Horizontal motion. Duration = 4m.

The earthquake began with preliminary tremor, which lasted for about 15s during which the motion in the *EW* direction was much



greater than that in the *NS* direction just as was the case with the earthquake of April 5, 1881. The earlier portion of the shaking was superposed with traces of ripples which were insignificant. At the termination of the preliminary tremor the following maximum motion suddenly took place:—

Max. $2a = 6.2\text{mm}$, Direction from *E* to *W*, $T_0 = 1.4\text{s}$; $V = 14\text{mm/s}$,

$A = 63\text{mm/s}^2$.

The motion of the earth's particle at the commencement of the principal portion represented in the annexed diagram, where *AB* is the maximum motion) was nearly similar at *Hongo* and *Hitotsubashi*. The character of motion was, however, altogether different at these two places. Thus, at *Hongo* the principal motion consisted of a single initial maximum vibration, followed by ripples; while at *Hitotsubashi* it consisted of a series of large vibrations of period much slower than at *Hongo*.

The relation between $2a$ and T of the horizontal motion is given in the next table.—

HITOTSUBASHI : HORIZONTAL MOTION.

2a (mm)	T (sec.)	2a (mm)	T (sec.)
6.2 } 5.3 } 5.5(mean) 4.8 }	1.4 } 1.1 } 1.2(mean) 1.1 }	2.9 } 2.9 } 2.8 } 2.8(mean) 2.8 } 2.8 }	0.9 } 0.83 } 1.1 } 0.9(mean) 0.75 } 0.9 }
4.5 } 4.1 } 4.2(mean) 3.9 }	0.83 } 1.1 } 1.0(mean) 1.1 }		
3.6 } 3.5 } 3.4(mean) 3.3 } 3.3 }	1.1 } 0.98 } 1.0(mean) 0.9 } 1.1 }	2.5 } 2.5 } 2.5(mean) 2.5 } 2.3 }	0.84 } 1.1 } 0.99(mean) 0.9 } 1.1 }
3.3 } 3.0 } 3.0(mean) 3.0 } 3.0 } 3.0 } 3.0 }	0.94 } 1.1 } 0.96(mean) 0.98 } 0.98 } 0.83 } 0.9 }	2.0 } 2.0 } 1.7(mean) 1.8 } 1.6 } 1.3 }	0.75 } 0.75 } 0.83 } 0.77(mean) 0.68 } 0.83 }

The measurement in the above table is taken from the earlier portion of the diagram. In the very end portion, the average period deduced from 24 vibrations was 0.86s.

Taking each of the horizontal components separately, the numbers of vibrations and the average period during the successive 16.5s were as follows :—

<i>EW</i> component.		<i>NS</i> component.	
Number of vibrations during 16.5s.	Average period (sec.).	Number of vibrations during 16.5s.	Average period(sec.).
18	0.92	18	0.92
17	0.97	19	0.87
18	0.92	17	0.97
17	0.97		
17	0.97		
17	0.97		
18	0.92		
17	0.97		
18	0.92		
18	0.92		

0.95(mean)

0.93(mean)

The average period of vibration was thus constant.

Vertical motion. Duration = 3m.

The vertical motion existed in a considerable amount but was rather slow in period, the character being very different from that at *Hongo*. Like the horizontal motion, it began with preliminary tremor which lasted for about 15s, followed by large displacements exactly simultaneous with the horizontal components. The maximum vertical motion occurred slightly later than the maximum horizontal motion:—

$$\text{Max. } 2a = 0.75 \text{ mm, } T_0 = 1.0\text{s; } V = 2.4 \text{ mm/s, } A = 15. \text{ mm/s}^2$$

The vertical vibrations were very slow, their period being at first identical with that of the horizontal. The period lengthened towards the end, the amplitude remaining, however, sensibly constant. Thus the average period was, during the first 30 seconds, 9.4s, while at the end it was 1.7s.

Hongo.

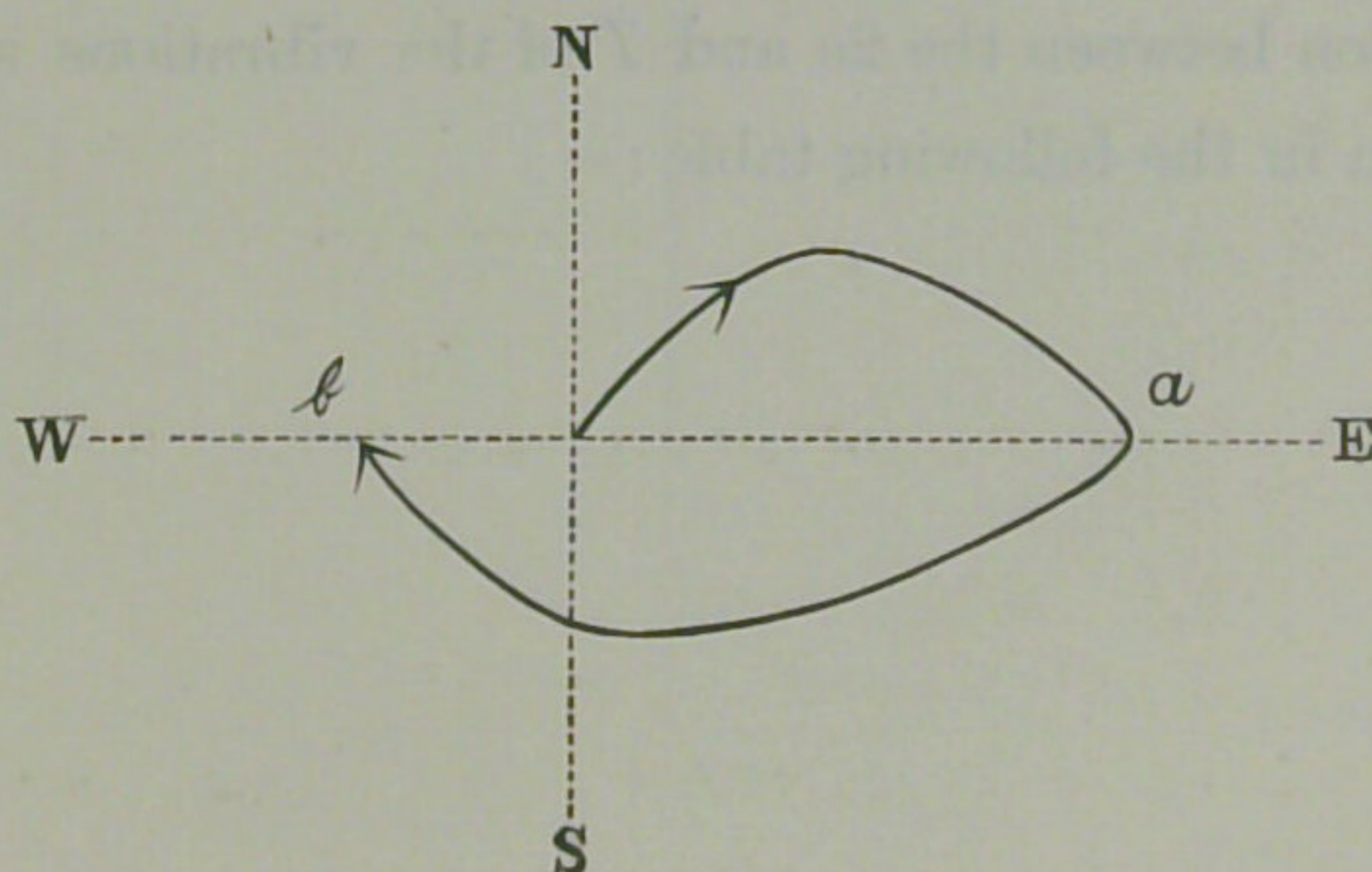
Horizontal motion.

Duration = 130s *EW* component.

„ = 180 *NS* „

The earthquake began as usual with preliminary tremor which lasted for about 4s, when there occurred suddenly the following maximum vibration:—

$$\text{Max. } 2a = 4.0 \text{ mm, } \textit{Direction from } E \text{ to } W, T_0 = 1.0\text{s; } V = 13 \text{ mm/s, } A = 80 \text{ mm/s}^2$$



The initial movement in the principal portion is illustrated in the

annexed diagram, ab being the maximum displacement. The latter was the only large wave in the whole earthquake, the rest of the principal portion consisting of quick vibrations or ripples. In the end portion, large slow undulations appeared. Although the greatest displacement occurred in the EW component, yet otherwise the motion was greater in the NS component; this being the case especially towards the end of the earthquake.

The maximum of the ripples, which lasted for the first 35s, was the following:—

$$\text{Max. } 2a = 1.1 \text{ mm, } T_0 = 0.23\text{s} : V = 15\text{mm/s, } A = 400\text{mm/s}^2$$

The average period of the ripples was as follows.—

EW component. . . Aver. period = 0.18s (deduced from 49 vibrations),
 NS „ . . . Aver. period = 0.18s („ „ 77 „).

After the disappearance of the ripples, the motion became simpler and consisted of regular vibrations. The numbers of the latter in the NS component during the successive 22s were as follows:—17,19,17,19, 18. . . giving a mean period of 1.2s. Traces of similar waves were also to be recognized in the earlier portion. The period of vibration in the NS component remained constant till the very end. The average period deduced from 30 vibrations in the end portion of the EW component was 0.73s. The maximum of the vibrations in the end portion was the following:—

$$2a = 2 \text{ mm, } T_0 = 1.3 \text{ s ; } V = 4.8 \text{ mm/s, } A = 23 \text{ mm/s}^2.$$

The relation between the $2a$ and T of the vibrations after the 70th second is given in the following table:—



HONGO : HORIZONTAL MOTION.

NS component.		EW component.		
2a (mm)	T (sec.)	2a (mm)	Number of vibrations.	Average T (sec.)
1.4	1.9	0.94	1	1.0
1.2	1.3			
1.0	1.3			
0.8	1.1			
0.8	2.0			
0.7	1.0			
0.7	1.4			
0.7	1.3			
0.7	1.3			
0.7	1.3			
0.6	0.98	very small	4	0.51
0.6	1.06	"	4	0.57
0.6	1.4	"	3	0.52
0.6	1.2	"	7	0.47
0.6	1.1	"	3	0.52
0.6	1.5	"	4	0.58
0.6	1.5	"	5	0.55
0.4	1.2	"	5	0.69
0.4	0.76	"	3	0.69
0.4	1.5	"	2	0.72
0.4	1.2			
0.4	1.1			
0.3	1.1			
0.3	1.1			
0.3	1.3			
0.2	0.64			
0.2	0.85			
0.2	1.0			

The average period deduced from 23 vibrations in the very end portion of the NS component was 0.94s.

Vertical motion. Duration=30s.

The vertical motion, which was active during the first 32 seconds, was irregular and consisted of some very small vibrations mixed with comparatively large undulations, the character being similar to that of the horizontal motion. In this case, therefore, the vertical motion might be due, partly at least, to the vertical component of the normal or transverse motion and not a purely surface motion.

There was no prominent wave in the vertical component which

might correspond to the maximum horizontal vibration, though otherwise the active movements took place, in general, simultaneously in the two components.

$$\text{Max. } 2a = 0.25\text{mm}, T_o = 0.31\text{s}; V = 2.5\text{mm/s}, A = 50\text{mm/s.}^2$$

Towards the end, the vibrations became regular and had an average period of 0.2s.

The relation between the $2a$ and T of the vertical vibrations is given in the following table.

HONGO : VERTICAL MOTION.

2a (mm)	T (sec.)	2a (mm)	Number of vibrations.	Average T (sec.)
0.33	0.46	very small	1	0.11
0.3	0.46			
0.3	0.40			
0.25	0.38			
0.21	0.27	''	1	0.14
0.20	0.36	''	1	0.13
0.20	0.36	''	1	0.18
0.19	0.30	''	1	0.16
0.19	0.34	''	1	0.19
0.18	0.27	''	3	0.21
0.16	0.30	''	1	0.23
0.13	0.23	''	4	0.20
0.13	0.21	''	3	0.27
0.13	0.24	''	4	0.22
0.13	0.26	''	4	0.16
0.13	0.21	''	8	0.15
0.1	0.19	''	18	0.20
0.09	0.23			
0.08	0.15			
0.08	0.23			
0.06	0.19			
0.06	0.19			
0.06	0.15			

Eqke No. 70. April 30, 1888 : 5.41.38 a.m.

Observation at the *Cent. Met. Observatory* :—

Duration. ———

Direction. *E - W*.
 Max. H.M. Very small.
 Character. Gentle.

Eqke No. 71. April 27, 1888 ; 8.34.34 a.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 2m.
 Direction. *SW—NE*.
 Max. H.M. 0.2mm (period = 1.5s).
 Character. Gentle.

Hitotsubashi.

A small earthquake, whose motion consisted entirely of regular gentle vibrations, there being no vertical component. Duration = 110s.

Max. $2a = 0.35$ mm, $T_0 = 0.91$ s ; $V = 1.2$ mm/s, $A = 8$ mm/s²

The average period was as follows :—

EW component 0.87s (deduced from 27 vibrations).

NS „ 0.89s („ „ 11 „).

Eqke No. 72. May 5, 1888 ; 8.52. 24 p.m.

A tremor observed at the *Cent. Met. Observatory*.

Eqke No. 73. May 8, 1888 ; 4.7.56 a.m.

A tremor observed at the *Cent. Met. Observatory*.

Eqke No. 74. May 8, 1888 ; 4.51.41 a.m.

A tremor observed at the *Cent. Met. Observatory*.

Eqke No. 75. May 10, 1888 ; 10.12.0 a.m.

A tremor observed at the *Cent. Met. Observatory*.

Eqke No. 76. May 13, 1888 ; 4.51.52 a.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 10s

Direction. *NW-SE.*

Max. H.M. 0.2 mm (period=0.5s)

Character. Quick.

Hitotsubashi.

A small and gentle earthquake, whose motion was almost entirely in the *EW* direction ; there being no vertical motion. Duration = 60s.

Max.2a = 0.35 mm, $T_o = 0.75s$; $V = 1.6$ mm/s, $A = 14$ mm/s.²

The average period, deduced from 30 vibrations in the *EW* component, was 0.76s.

The motion presented a series of maxima which occurred at the commencement and at 5.5s, 10.2s, 14.9s, 19.2s, and 23.9s, respectively after the latter ; the average interval being 4.8s.

Eqke No. 77. May 13, 1888 : 11.17.41 p.m.

a tremor observed at the *Cent. Met. Observatory.*

Eqke No. 78. May 22, 1888 : 6.9.20 p.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 4m 30s.

Direction. *ESE-WNW.*

Max. H.M. 1.5 mm (period = 2.6s (?))

Max. V.M. 0.2 mm (period = 0.7s).

Character. Gentle.

Hitotsubashi.

Horizontal motion. Duration = 4m.

The preliminary tremor lasted for about 10s and consisted of vibrations, whose period was nearly equal to that in the succeeding portions.

Max.2a = 2.2 mm, $T_o = 0.97s$; $V = 7.1$ mm/s, $A = 46.1$ mm/s.²

The average period deduced from 40 vibrations during the first 1m of the *EW* component, was 0.83s, that deduced from 34 vibrations in the end portion of the same component being also 0.84s.

Vertical motion. Duration = about 2m.

The duration of the preliminary tremor was equal to that of the horizontal.

Max. $2a = 0.4\text{mm}$, $T_o = 0.70\text{s}$; $V = 1.8\text{ mm/s}$, $A = 16\text{ mm/s}^2$

The period was unusually long, the average value deduced from 17 vibrations, being 0.64s.

Hongo.

Horizontal motion. Duration = 140s.

The motion, which was greater in the *EW* than in the *NS* component, was at first a little irregular, but soon became regular.

Max. $2a = 0.74\text{ mm}$, $T_o = 0.78\text{s}$; $V = 3\text{ mm/s}$, $A = 25\text{ mm/s}^2$

The maximum was, however, not prominently large, there being a great number of vibrations of nearly equal amplitude. The average period of vibration, after the disappearance of ripples was as follows:—

- EW* component 0.54s (deduced from 58 vibrations);
- NS* „ 0.85s („ „ 26 „).

Vertical motion. Duration = 20s.

This began with small waves.

Max. $2a = 0.1\text{ mm}$, $T_o = 0.37\text{s}$; $V = 0.9\text{ mm/s}$, $A = 14.4\text{ mm/s}^2$

The average period deduced from 17 vibrations was 0.18s.

Eqke No. 79. May 24, 1888; 9.35.37 a.m.

Observation at the *Cent. Met. Observatory*:—

Duration. 60s.

Direction. *E—W*.

Max. H.M. Small.

Character. Gentle.

Eqke No. 80. May 24, 1888; 11.45.5 a.m.

A tremor, which was felt at *Hongo*, but did not start the machines.

Eqke No. 81. May 26, 1888; 6.17.14 p.m.

A tremor. The seismographs at *Hitotsulashi* recorded very slight movements.

Eqke No. 82. May 27, 1888; 7.5.9 p.m.

Observed as a tremor at the *Cent. Met. Observatory*.

Hitotsubashi.

Duration=60s. This was a very small earthquake, whose motion was chiefly in the *EW* direction and consisted of regular gentle vibrations of a constant period; there being no vertical component. The maximum occurred at the commencement:—

$$\text{Max. } 2a = 0.25\text{mm}, T_o = 0.71\text{s}; V = 1.1 \text{ mm/s}, A = 10 \text{ mm/s}^2.$$

The average period, deduced from 28 vibrations in the *EW* component, was 0.74s.

Eqke No. 83. June 3, 1888; 7.53.8 a.m.

Observation at the *Cent. Met. Observatory*:—

Duration. 3m.

Direction. *WNW-ESE*.

Max. H.M. Small.

Character. Gentle.

Hitotsubashi.

Horizontal motion. Duration=180s.

The motion, which was greater in the *EW* than in the *NS* component, was irregular at first but soon became regular. There was no prominently large displacement, the motion being made up of a series of vibrations of nearly constant period, the amplitude decreasing very gradually.

$$\text{Max. } 2a = 1.8\text{mm}, T_o = 0.94\text{s}; V = 6 \text{ mm/s}, A = 40 \text{ mm/s}^2.$$

The average period, deduced from 21 vibrations in the principal portion of the *EW* component, was 0.80s; that deduced from 48 vibrations in the end portion of the same component was 0.86s.

Vertical motion. Duration=25s.

The vertical motion, the duration of whose preliminary tremor was equal so that of the horizontal, consisted of slow vibrations, whose average period deduced from 7 largest vibrations was 0.63s.

$$\text{Max. } 2a = 0.2\text{mm}, T_o = 0.62\text{s}; V = 0.5 \text{ mm/s}, A = 2.6\text{mm/s}^2$$

Eqke No. 84. June 12, 1888; 9.6.27 p.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 20s.

Direction. *NWN-SES*.

Max. H.M. 0.4mm (period=1.2s)

Character. Gentle.

Hitotsubashi.

Duration=100s. There was no vertical component. The motion which was at first slightly superposed with ripples soon became regular and constant in period.

Max.2a=0.3 mm, $T_o = 0.88s$; $V = 1.1\text{mm/s}$, $A = 8.0\text{mm/s}^2$.

The average period deduced from 40 vibrations was 0.78s.

Hongo.

Horizontal motion. Duration=60s.

The motion occurred equally in the two components. At first the vibrations were very quick, the average period being 0.23s. Towards the end, the vibrations became very slow; the average period deduced from 9 vibrations being 2.0s.

Max.2a=0.16mm, $T_o = 0.22s$; $V = 2.3\text{mm/s}$, $A = 66\text{mm/s}^2$.

Vertical motion. Duration=10s.

The vertical motion, whose maximum occurred at the commencement, was well pronounced in comparison to the preliminary tremor of the horizontal.

The period of the vertical motion was identical with that of the small movements in the earlier portion of the horizontal; there being during the first 2.9s interval 14 vibrations in the horizontal and also exactly the same number in the vertical component. Thus it may be supposed that the vertical motion and the horizontal ripples are related to one another, and are possibly components of surface waves; the earth particle describing a small elliptical orbit, whose vertical axis is comparable in magnitude to the horizontal.

Max.2a=0.06mm, $T_o = 0.23s$; $V = 0.9\text{mm/s}$, $A = 23\text{mm/s}^2$.

The motion consisted of small regular waves, whose average period was 0.26s.

Eqke No. 85. June 15, 1888 ; 0.21.25 a.m.

A tremor observed at the *Cent. Met. Observatory* :—

Eqke No. 86. June 18, 1888 ; 2.20.31 p.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 100s.

Direction. *SE-NW*.

Max. H. M. 0.3mm (period = 0.8s).

Character. Quick.

Hitotsubashi.

Horizontal motion. Duration = 120s.

As usual with earthquakes of a moderate intensity, this consisted of a great number of vibrations nearly constant in amplitude and period, none being prominently large. The motion was much greater in the *EW* than in the *NS* component.

Max. $2a = 1.0$ mm, $T_o = 0.70$ s ; $V = 4.5$ mm/s, $A = 41$ mm/s²

The average period deduced from 58 vibrations was 0.76s.

Vertical motion. Only doubtful traces.

Hongo.

Horizontal motion. Duration = 70s.

The character of motion was much similar to that of the earthquake of June 12, 1888. The motion began with small irregular vibrations, but afterwards became lengthened in period.

Max. $2a = 0.2$ mm, $T_o = 0.6$ s ; $V = 0.52$ mm/s, $A = 2.7$ mm/s².

In the *EW* component, the ripples had an average period of 0.42s, these being superposed on slower undulations of an average period of 1.3s. In the *NS* component, the corresponding average periods were respectively 0.46s and 1.2s ; towards the very end, the waves had an average period of 2.1s.

Eqke No. 87. June 18, 1888 ; 3.17.6 p.m.

A tremor observed at the *Cent. Met. Observatory*.

Eqke No. 88. June 18, 1888 ; 9.59.14 p.m.

A tremor observed at the *Cent. Met. Observatory*.

Eqke No. 89. June 19, 1888 ; 6.29.57 a.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 20s.

Direction. *E-W*.

Max. H.M. 0.2 mm (period = 0.8s)

Character. Quick.

Eqke No. 90. June 22, 1888 ; 7.6.25 a.m.

A tremor observed at the *Cent. Met. Observatory*.

Eqke No. 91. June 24, 1888 ; 11.8.20 p.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 10s.

Direction. *E-W*.

Max. H.M. Small.

Character. Quick.

Eqke No. 92. July 2, 1888 ; 4.51.56 a.m.

Observed as a tremor at the *Cent. Met. Observatory*.

Hitotsubashi.

Duration = 30s. The motion which was very small, was almost entirely in the *EW* direction, there being no vertical component.

Max. $2a = 0.25$ mm, $T_0 = 0.57$ s ; $V = 1.4$ mm/s, $A = 16$ mm/s.²

Eqke No. 93. July 7, 1888 ; 9.37.37 a.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 180s.

Direction. *E-W*.

Max. H.M. Small.

Character. Gentle.

Hitotsubashi.

Duration = 80s. The motion, which consisted of slow regular vibra-

tions, showed alternations of maximum and minimum groups, the following maximum vibration having occurred in the later portion of the earthquake :—

$$\text{Max. } 2a = 0.83 \text{ mm, } T_o = 0.9\text{s}; V = 2.9 \text{ mm/s, } A = 20 \text{ mm/s}^2$$

The average period deduced from 25 vibrations was 0.98s.

Eqke No. 94. July 7, 1888; 5.25.43 p.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 60s.

Max. H.M. Small.

Character. Gentle.

Hitotsubashi.

Duration = 60s. This was a very small and gentle earthquake, the motion being chiefly in the *EW* direction. There was no vertical component.

$$\text{Max. } 2a = 0.45 \text{ mm, } T_o = 0.83\text{s}; V = 1.7 \text{ mm/s, } A = 13 \text{ mm/s}^2$$

The average period deduced from 15 vibrations in the *EW* component was 0.85s.

Eqke No. 95. July 11, 1888; 3.38.35 p.m.

A tremor observed at the *Cent. Met. Observatory.*

Eqke No. 96. July 14, 1888; 7.31.59 a.m.

A tremor observed at the *Cent. Met. Observatory.*

Eqke No. 97. July 14, 1888; 4.42.44 p.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 180s.

Direction. *SWS—NEN.*

Max. H.M. 0.6mm (period = 2.4s)

Character. Gentle.

Hitotsubashi.

Duration = 50s. The motion was entirely in the *EW* direction, there

being no vertical component. The vibrations were perfectly regular and constant in period; there being, however, some alternations of maximum and minimum groups.

Max. $2a = 0.43$ mm, $T_o = 0.73$ s; $V = 1.9$ mm/s, $A = 16$ mm/s.²

The average period deduced from 27 vibrations in the *EW* component was 0.71s.

(The *Hitotsubashi* diagrams of small earthquakes like the present indicate usually no distinct preliminary tremor, lost probably on account of smallness of the movements.)

Eqke No. 98. July 22, 1888; 2.27.48 a.m.

A tremor observed at the *Cent. Met. Observatory*.

Eqke No. 99. July 24, 1888; 7.57.43 a.m.

A tremor observed at the *Cent. Met. Observatory*.

Eqke No. 100. July 29, 1888; 9.48.21 p.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 90s.

Direction. *E-W*.

Max. H.M. 0.2 mm (period = 1.0s).

Max. V.M. Very small.

Character. Gentle.

Hitotsubashi.

Duration = 100s. The motion was greater in the *EW* than in the *NS* direction, there being no vertical component.

Max. $2a = 0.75$ mm, Direction *EW*, $T_o = 0.8$ s; $V = 2.9$ mm/s, $A = 22$ mm/s.²

The average period of vibration was as follows :—

EW component 0.77s (deduced from 22 vibrations);

NS „ 1.2s („ „ 9 „).

Eqke No. 101. Aug. 1, 1888; 9.25.18 p.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 90s.

Direction. *E-W*.

Max. H.M. 0.2 mm(period = 0.8s).

Character. Quick.

Hitotsubashi.

Duration = 100s. A small and gentle earthquake, whose motion was almost entirely in the *EW* direction, there being no vertical component. There were several alternations of maximum and minimum groups.

Max. $2a = 0.83$ mm, $T_o = 0.72$ s; $V = 3.6$ mm/s, $A = 31$ mm/s.²

The average period of vibration was as follows :—

EW component 0.74s (deduced from 24 vibrations),

NS „ 0.93s („ „ 10 „).

It will be observed that this earthquake was similar to some of the preceding. The periods in the two horizontal components were, as often happens, not alike.

Eqke No. 102. Aug. 11, 1888; 9.31.42 a.m.

A tremor observed at the *Cent. Met. Observatory*.

Eqke No. 103. Aug. 12, 1888; 11.42.27 a.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 180s.

Direction. *SWS—NEN*.

Max. H.M. 0.4 mm(period = 1.2s).

Character. Gentle.

Hitotsubashi.

Duration = 3 m. The earthquake, which began very gently, gradually attained the full amplitude and then remained nearly of the same size through a considerable time interval. The motion was much greater in the *EW* than in the *NS* direction, there being no vertical component.

Max. $2a = 1.1$ mm, $T_o = 0.81$ s; $V = 4.3$ mm/s, $A = 34$ mm/s.²

The average period, deduced from 117 vibrations in the *EW* compo-

ment, was 0.78s.

Hongo.

Duration = about 3 m. No vertical motion.

Max. $2a = 0.5$ mm.

Eqke No. 104. Aug. 17, 1888 ; 3.49.50 a.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 70s.

Direction. *E-W.*

Max. H.M. 0.2 mm (period = 1.0s)

Character. Gentle.

Eqke No. 105. Aug. 18, 1888 ; 1.22.0 a.m.

A tremor observed at the *Cent. Met. Observatory.*

Hitotsubashi.

Duration = 100s. No vertical motion.

Max. $2a = 0.2$ mm, $T_0 = 0.88$ s ; $V = 0.7$ mm/s, $A = 5$ mm/s²

The average period, deduced from 27 vibrations, was 0.79s.

Hongo.

The motion was very small.

Eqke No. 106. Aug. 19, 1888 ; 9.19.26 a.m.

A tremor observed at the *Cent. Met. Observatory.*

Eqke No. 107. Aug. 19, 1888 ; 11.47.25 a.m.

A tremor observed at the *Cent. Met. Observatory.*

Eqke No. 108. Sept. 2, 1888 ; 5.45.0 a.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 30 s.

Direction. *E-W.*

Max. H.M. Very small.

Character. Gentle.

Eqke No. 109. Sept. 4, 1888 ; 5.10.0 a.m.

A tremor observed at the *Cent. Met. Observatory.*

Eqke No. 110. Sept. 4, 1888 ; 1.36.11 p.m.

A tremor observed at the *Cent. Met. Observatory.*

Eqke No. 111. Sept. 5, 1888 ; 0.6.35 a.m.

A tremor observed at the *Cent. Met. Observatory.*

Eqke No. 112. Sept. 6, 1888 ; 4.9.25 a.m.

A tremor observed at the *Cent. Met. Observatory.*

Eqke No. 113. Sept. 10, 1888 ; 9.22.0 a.m.

A tremor observed at the *Cent. Met. Observatory.*

Eqke No. 114. Sept. 11, 1888 ; 8.34.54 a.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 25s.

Direction. *E-W.*

Max. H.M. 0.4mm (period = 0.4s)

Max. V.M. Small.

Character. Quick.

Eqke No. 115. Sept. 18, 1888 ; 2.45.39 a.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 30s.

Direction. *E-W.*

Max. H.M. Quick.

Hitotsubashi.

The motion was chiefly in the *EW* direction.

Max. 2a = 0.1mm.

Hongo.

Motion was very slight. No vertical component.

Eqke No. 116. Sept. 24, 1888; 5.24.30 a.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 20s.

Direction. *E-W*.

Max. H.M. Very small.

Character. Gentle.

Hitotsubashi.

Duration = 40s. Motion was chiefly in the *EW* direction, there being no vertical component.

Max. $2a = 0.25$ mm.

The period was constant.

Eqke No. 117. Sept. 24, 1888; 5.37.13 p.m.

A tremor observed at the *Cent. Met. Observatory*.

Eqke No. 118. Sept. 28, 1888; 7.5.21 a.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 30s.

Max. H.M. Small.

Character. Quick.

Hongo.

The motion was very small.

Eqke No. 119. Oct. 9, 1888; 1.7.55 a.m.

A tremor observed at the *Cent. Met. Observatory*.

Eqke No. 120. Oct. 10, 1888; 4.20.24 p.m.

Observation at the *Cent. Met. Observatory* :—

Duration = 30s.

Max. H.M. Small.

Eqke No. 121. Oct. 12, 1888; 7.40.56 a.m.

Observed as a tremor at the *Cent. Met. Observatory*.
Hitotsubashi.

The motion was very slight.

Eqke No. 122. Oct. 20, 1888 ; 6.15.16 a.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 2m.

Direction. *NEN-SWS*.

Max. H.M. 1.2mm (period = 0.5s)

Max. V.M. 0.5mm (period = 0.5s)

Character. Quick.

Remark. The earthquake began with quick horizontal and vertical movements. There were three prominent vertical vibrations, of which the first was the maximum. The horizontal motion was active during the first 20s.

Hitotsubashi.

Horizontal motion. Duration = 120s.

The earthquake began with preliminary tremor, which lasted for 7s, when the motion became suddenly active, the amplitude being much larger in the *EW* than in the *NS* component.

Max. $2a = 0.7$ mm, $T_0 = 0.66$ s ; $V = 3.3$ mm/s, $A = 31$ mm/s²

The motion was of maximum intensity immediately after the preliminary tremor. The average period, deduced from 32 vibrations, was 0.78s.

Vertical motion. Duration = 40s.

The vertical motion, whose preliminary tremor consisted of very small movements, became active simultaneously with the horizontal.

Max. $2a = 0.18$ mm, $T_0 = 0.38$ s ; $V = 1.5$ mm/s, $A = 25$ mm/s²

This maximum occurred not exactly at the same moment as the maximum horizontal motion.

Hongo.

Horizontal motion. Duration = 70s. The motion, which occurred equally in the two horizontal components, commenced with the following maximum :—

Max. $2a = 0.6$ mm, Direction *S*.

A second maximum, which occurred later on, was the following:—

$2a = 0.34$ mm, $T_o = 0.55$ s; $V = 1.9$ mm/s, $A = 21$ mm/s.²

The vibrations were at first irregular, but soon became regular. The average period deduced from 11 well defined vibrations was 0.52s.

Vertical motion. Duration = 20s. The motion, which was active during the first 10s, consisted of small vibrations, whose average period deduced from 8 vibrations was 0.28s. There was no well defined large vibration.

Max. $2a = 0.13$ mm, $T_o = 0.38$ s; $V = 1.1$ mm/s, $A = 20$ mm/s.²

Eqke No. 123. Nov. 2, 1888; 1.48.1 p.m.

Observation at the *Cent. Met. Observatory*:—

Duration. 60s.

Direction. *E-W*.

Max. H.M. 0.3mm (period = 0.8s).

Character. Quick.

Hitotsubashi.

Horizontal motion. Duration = 160s. This was a moderate earthquake, whose motion was much greater in the *EW* than in the *NS* component and which consisted of perfectly regular vibrations.

The preliminary tremor lasted for 10s and consisted of small slow vibrations of an average period of 0.58s. This was suddenly followed by large movements.

Max. $2a = 1.2$ mm, Direction *SW*, $T_o = 0.77$ s; $V = 4.9$ mm/s,

$A = 40$ mm/s.²

The average period deduced from 38 vibrations in the *EW* component was 0.71s.

Vertical motion. Duration = 30s. The motion began very gradually. The following maximum occurred a little later than the horizontal maximum:—

Max. $2a = 0.2$ mm, $T_o = 0.4$ s; $V = 1.6$ mm/s, $A = 25.6$ mm/s.²

Hongo.

Horizontal motion. Duration = 40s. The motion began with the following maximum :—

Max. $2a = 0.54$ mm, Direction *SW*.

In the subsequent portion the motion was small (Max. $2a = 0.1$ mm) and seemed to be merely the residual of the above initial movement.

In the earlier part of the *EW* component, the average period was 0.21s, that in the corresponding part of the *NS* component being 0.23s.

Vertical motion. Duration = 20s. The motion was very small; the average period deduced from 15 vibrations was 0.17s.

Eqke No. 124. Nov. 3, 1888 ; 0.51.14 a.m

Observation at the *Cent. Met. Observatory* :—

Duration. 90s.

Direction. *E-W*.

Max. H.M. 0.3mm (period = 0.5s).

Max. V.M. Small.

Character. Quick.

Hongo.

Duration = 20s. No vertical motion.

Max. $2a = 0.14$ mm, $T_0 = 0.34$ s ; $V = 1.3$ mm/s, $A = 2.4$ mm/s²

The motion consisted of irregular vibrations.

Eqke No. 125. Nov. 3, 1888 ; 8.13.33 a.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 4m 30s.

Direction. *SW-NE*.

Max. H.M. 1.9mm (period = 0.4s).

Max. V.M. 0.5mm (period = 0.4s).

Character. Quick.

Remark. The preliminary tremor lasted for 7s, when both the vertical and the horizontal components became large. The maximum vertical vibration occurred at the 16th second, the motion remaining active

for the next 3s. The maximum horizontal motion occurred at the 10th second, the motion remaining active for the next 20s.

(This earthquake which was moderately severe was unfortunately not recorded at *Hitotsubashi* and *Hongo*.)

Eqke No. 126. Nov. 5, 1888 ; 4.22.55 a.m.

Observed as a tremor at the *Cent. Met. Observatory*.

Hitotsubashi.

Duration = 60s. The motion was almost entirely in the *EW* component.

Max. $2a = 0.25\text{mm}$, $T_o = 0.82\text{s}$; $V = 0.96\text{ mm/s}$, $A = 7.1\text{mm/s}^2$

The average period deduced from 18 vibrations was 0.77s.

Eqke No. 127. Nov. 6, 1888 ; 4.38.37 p.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 180s.

Max. H.M. 0.2mm (period = 2.2s)

Character. Gentle.

Eqke No. 128. Nov. 7, 1888 ; 10.27.34 p.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 240 s.

Direction. *E-W*.

Max. H.M. 0.5mm (period = 3.5s (?)).

Character. Gentle

Hitotsubashi.

Duration = 250s. No vertical motion.

This was a very small earthquake, the motion consisting of slow vibrations.

Max. $2a = 0.36\text{mm}$, $T_o = 2.8\text{s}$; $V = 0.4\text{ mm/s}$, $A = 0.9\text{ mm/s}^2$

Eqke No. 129. Nov. 10, 1888 ; 1.37.44 p.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 90s.

Direction. *WNW-ESE*.
 Max. H.M. 0.3mm(period = 1.8s).
 Character. Gentle.

Hitotsubashi.

Duration = 2m. No vertical motion.

The motion, which was chiefly in the *EW* direction, consisted of small regular vibrations.

Max. $2a = 0.75$ mm, $T_o = 0.87$ s; $V = 2.7$ mm/s, $A = 19.2$ mm/s.²

The average period of vibration was as follows:—

EW component 0.85s(deduced from 34 vibrations),
NS „ 0.65s(„ „ 13 „).

Eqke No. 130. Nov. 16, 1888; 0.42.49 a.m.

Observed as a tremor at the *Cent. Met. Observatory*.—

Hitotsubashi.

Duration = 60s. No vertical motion.

The motion, which was entirely in the *EW* direction, was of maximum amplitude at the commencement, the subsequent portion presenting alternations of maximum epochs.

Max. $2a = 0.4$ mm, $T_o = 0.95$ s; $V = 1.3$ mm/s, $A = 8.5$ mm/s.²

The average period, deduced from 26 vibrations in the *EW* component, was 0.9s

Eqke No. 131. Nov. 20, 1888; 0.53. 29 a.m.

Observation at the *Cent. Met. Observatory*:—

Duration. 150s.
 Direction. *E-W*.
 Max. H.M. 0.2mm(period = 0.9s).
 Character. Gentle.

Hitotsubashi.

Duration = 3m. The duration was very long in comparison to the amplitude, which remained nearly constant during a considerable interval of time. The motion was chiefly in the *EW* direction, there being

no vertical motion.

Max. $2a = 0.75\text{mm}$, $T_o = 0.75\text{s}$; $V = 3.1\text{mm/s}$, $A = 25.3\text{mm/s}^2$

The average period, deduced from 17 vibrations in the *EW* component, was 0.77s.

Hongo.

The motion was very small.

Eqke No. 132. Nov. 22, 1888; 1.27.43 p.m.

Observed as a tremor at the *Cent. Met. Observatory.*

Hitotsubashi.

Duration = 170s. The motion was chiefly in the *EW* direction, there being no vertical component.

Max. $2a = 0.63\text{mm}$, $T_o = 0.85\text{s}$; $V = 2.3\text{mm/s}$, $A = 16.5\text{mm/s}^2$

The average period, deduced from 29 vibrations in the *EW* component, was 0.8s.

Eqke No. 133. Nov. 23, 1888; 5.13.30 p.m.

A tremor observed at the *Cent. Met. Observatory.*

Eqke No. 134. Nov. 24, 1888; 2.3.23 a.m.

Observation at the *Cent. Met. Observatory* : —

Duration. 240s.

Direction. *NW-SE.*

Max. H.M. 0.4mm (period = 1.4s).

Character. Gentle.

Eqke No. 135. Nov. 25, 1888; 4.50.15 p.m.

Observation at the *Cent. Met. Observatory* : —

Duration. 15s.

Direction. *E-W.*

Max. H.M. 0.2mm (period = 0.5s).

Character. Quick.

Hitotsubashi.

Duration = 45s. The motion, which was entirely in the *EW* direction, consisted of perfectly regular small vibrations, with several alternations of maximum and minimum groups.

$$\text{Max. } 2a = 0.5\text{mm}, T_o = 0.92\text{s}; V = 1.7 \text{ mm/s}, A = 12 \text{ mm/s}^2$$

The average period deduced from 18 vibrations was 0.94s.

Hongo.

Horizontal motion. Duration = 15s. The motion consisted of very small vibrations which were chiefly in the *NS* direction.

$$\text{Max. } 2a = 0.08\text{mm}, T_o = 0.26\text{s}.$$

The average period was about 0.26s.

Vertical motion. Duration = 15s. The motion was comparatively active and consisted of vibrations of an average period of 0.18s.

$$\text{Max. } 2a = 0.38\text{mm}, T_o = 0.18\text{s}; V = 0.7 \text{ mm/s}, A = 2.3 \text{ mm/s}^2$$

Eqke No. 136. Dec. 1, 1888; — —

Hitotsubashi.

The motion consisted of slow gentle movements of a long duration, chiefly in the *NS* direction.

Eqke No. 137. Dec. 3, 1888; 0.24.47 p.m.

Observation at the *Cent. Met. Observatory* : —

Duration. 120s.

Direction. *SE-NW*.

Max. H.M. 0.2mm (period = 1.8s).

Character. Gentle.

Hitotsubashi.

Duration = 120s. The earthquake, which was chiefly in the *EW* direction, consisted of a series of vibrations whose amplitude remained nearly constant. There was no vertical motion.

$$\text{Max. } 2a = 0.63\text{mm}, T_o = 0.79\text{s}; V = 2.5\text{mm/s}, A = 20\text{mm/s}^2$$

The average period, deduced from 38 vibrations in the *EW* component, was 0.77s.

Eqke No. 138. Dec. 6, 1888 ; 7.27.42 a.m.

Observed as a tremor at the *Cent. Met. Observatory.*

Hitostubashi.

Duration = 80s. This was a very small earthquake, whose motion occurred equally in the two horizontal components, there being no vertical vibration.

Max. $2a = 0.17\text{mm}$, $T_o = 0.68\text{s}$; $V = 0.79\text{mm/s}$, $A = 7.3\text{mm/s}^2$

The average period, deduced from 27 vibrations in the *EW* component, was 0.75s.

Hongo.

Motion was very small.

Eqke No. 139. Dec. 16, 1888 ; 4.19.3 a.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 20s.

Direction. *N-S.*

Max. H.M. Small.

Character. Gentle.

Hongo.

Horizontal motion. Duration = ? The motion consisted of a single prominent displacement, followed by small vibrations, the earthquake having been probably caused by some sudden blow, which acted only for a moment. The residual motion might be the free vibration of the ground. The *EW* component was much smaller than the *NS*. The numbers of vibrations in the latter component during the eight successive 10 seconds intervals after the greatest movement were :— 16, 18, 21, 19, 21, 21, 20, 20 ; the period being thus somewhat longer at the commencement, where the amplitude was also greater. Towards the end the period became constant.

Average period (*NS*) = 0.5s.

Vertical motion. Duration = ? The vertical motion consisted of vibrations, whose period remained constant and had an average value of 0.2s. It may be remarked that the period was very nearly equal to

the average period (0.24s) of the small ripples in the horizontal motion, whose duration was also nearly equal to that of the vertical motion.

Eqke No. 140. Dec. 21, 1888 ;—

Observed as a tremor at *Hitotsubashi* and *Hongo*.

Eqke No. 141. Dec. 28, 1888 ; 3.28.4 a.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 35s.

Direction. *E-W*.

Max. H.M. 0.2 mm (period = 1.7s).

Character. Gentle.

Hitotsubashi.

Duration = 60s. A very small earthquake, whose motion was greater in the *EW* than in the *NS* direction, there being no vertical motion.

Max. $2a = 0.2$ mm, $T_o = 0.8$ s ; $V = 0.8$ mm/s, $A = 6.1$ mm/s².

The average period, deduced from 8 vibrations in the *EW* component, was 0.86s.

Eqke No. 142. Jan. 1, 1889 ; 3.4.50 p.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 12s.

Direction. *SW-NE*.

Max. H.M. 0.5 mm (period = 0.3s).

Max. V.M. Small.

Character. Quick.

Hitotsubashi.

Duration = 70s. This was a small earthquake, whose motion was chiefly in the *EW* direction, there being no vertical component. The maximum vibration occurred at the commencement.

Max. $2a = 0.38$ mm, Direction *E*, $T_o = 0.87$ s ; $V = 1.4$ mm/s,

$A = 9.9$ mm/s².

The vibrations which followed the maximum rapidly decreased, the average period being as follows :—

EW component 0.81s (deduced from 42 vibrations) ;
NS „ 0.84s („ „ 15 „).

Hongo.

The motion was immeasurably small.

Eqke No. 143. Jan. 1, 1888 ; 7.5.30 p.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 120s.

Direction. *SW-NE*.

Max. H.M. 1.1mm (period = 0.1s (?)).

Max. V.M. 0.5mm (period = 0.3s).

Character. Quick.

Remark. The earthquake began with preliminary tremor, which lasted for 6s, and which were chiefly in the *EW* direction. Thereafter the motion became large in all the three components, executing 80 active vibrations during the next 10 seconds interval.

Area of disturbance. The earthquake originated in the boundary districts of Hitachi and Musashi and extended on the north to a radial distance of 60 *ri*, while on the south and the east it reached the sea shores. The land area of disturbance was 3430 sq. *ri* and included the following 16 provinces : Musashi, Shimosa, Kazusa, Awa, Hitachi, Shimotsuke, Kotsuke, Sagami, Kai, Izu (northern part), Suruga (eastern part), Shinano (eastern portion), Echigo (southern portion), Iwashiro (southern part), Iwaki (southern part), Rikuzen (southern portion). The area of strong motion was about 700 sq. *ri*, and extended over the following 6 provinces : Musashi (eastern part), Shimosa (western part), Hitachi (southern part), Shimotsuke (southern portion), Kotsuke (south-eastern portion), and Sagami (north-eastern portion). Within the latter area, sharp vertical motion was generally felt. In Tokyo the shock was strong enough to cause overturning of furnitures, etc. At Mito (province of Hitachi) some articles were thrown down from shelves, and at Kawachi District (province of Shimotsuke) *shoji* or paper covered sliding doors were almost thrown out of the grooves.

Eqke No. 144. Jan. 3, 1889 ; 7.58.6 a.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 120s.

Direction. *E-W*.

Max. H.M. 0.8mm (period = 1.5s).

Character. Gentle.

Eqke No. 145. Jan. 5, 1889 ; ———

Hongo.

Duration = 120s. The motion, which was irregular, consisted of gentle vibrations.

Max. $2a = 0.4$ mm, $T_o = 1.4$ s ; $V = 0.9$ mm/s, $A = 4.0$ mm/s.²

Eqke No. 146. Jan. 7, 1889 ; ———

Hitotsubashi.

Duration = 40s. The motion, which consisted of extremely small vibrations of a constant period, was chiefly in the *EW* direction, there being no vertical component.

Max. $2a = 0.1$ mm, $T_o = 0.82$ s ; $V = 0.4$ mm/s, $A = 2.9$ mm/s.²

The average period was as follows :—

EW component 0.81s (deduced from 24 vibrations),
NS „ 0.86s („ „ 12 „).

Eqke No. 147. Jan. 12, 1889 ; 8.34.3 p.m.

A tremor observed at the *Cent. Met. Observatory* :—

Eqke No. 148. Jan. 13, 1889 ; ———

Hitotsubashi.

Duration = 60s. A very small earthquake, whose motion was chiefly in the *EW* direction, there being no vertical component.

The preliminary tremor, whose duration was short, consisted of vibrations of the same period as in the subsequent portion. The vibrations in the *NS* component were small and ill defined.

Max. $2a=0.38$ mm, Direction *E-W*, $T_o=0.47$ s ; $V=2.5$ mm/s,
 $A=34$ mm/s.²

Eqke No. 149. Jan. 27, 1889 ; 2.28.47 p.m.

A tremor observed at the *Cent. Met. Observatory*.

Eqke No. 150. Jan. 29, 1889 ; —

Hitotsubashi.

Duration = 60s. This was a small earthquake, whose motion was chiefly in the *EW* direction, and which began very gradually. At about 8s from the commencement, the motion reached its full amplitude thence gradually decreasing.

Max. $2a=0.38$ mm, $T_o=0.56$ s ; $V=2.1$ mm/s, $A=23.9$ mm/s.²

The average period in the *EW* component was as follows :— 16 vibrations in the earlier part, whose $2a$ varied between 0.4mm and mm and had a mean value of 0.3 mm, had an average period of 0.6s ; while the 17 vibrations of small $2a$ in the end portion gave an average period of 0.55s.

Eqke No. 151. Feb. 5, 1889 ; 2.27.39. p.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 5s.

Direction. *N-S*.

Max. H.M. Small.

Eqke No. 152. Feb. 9, 1889 ; 7.41.38 a.m.

Observation at the *Cent. Met. Observatory*.

Duration. 10s.

Direction. *N-S*.

Max. H.M. Small.

Character. Quick.

Eqke. No. 153. Feb. 15, 1889 ; 5.14.3 a.m.

A tremor observed at the *Cent. Met. Observatory*.

Eqke No. 154. Feb. 18, 1889 ; 6.9.32 a.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 6m 12s.

Direction. *NW-SE*.

Max. H.M. 20.3 mm (period = 2.2s).

Max. V.M. 3.7 mm (period = 0.6s).

Character. Quick.

Remark. The earthquake began with small sharp horizontal and vertical vibrations. At the 15th second a sudden horizontal motion of 6 mm took place in the direction *SW-NE*, followed by 10 large vibrations which together lasted for 5 seconds, when the maximum displacement took place. The vertical motion became active also at the 15th second, its maximum occurring 5 seconds later than the horizontal maximum. The horizontal motion was more or less active during the first 5m 19s, and the vertical motion for the first 2m 4s.

Area of disturbance. The total land area of disturbance was 5750 sq. *ri*, and included the following 21 provinces :—Musashi, Sagami, Awa, Kazusa, Shimosa, Hitachi, Shimotsuke, Kotsuke, Kai, Suruga, Izu, Totomi, Shinano, Iwashiro, Iwaki, Rikuzen (south-eastern part), Uzen (south-eastern part), Echigo (central part), Mikawa (nearly whole of the province), Owari (northern part), Mino (eastern part). The area of *strong* motion was 1390 sq. *ri* and extended over the following 11 provinces :—Musashi, Sagami, Izu, Awa, Kazusa, Shimosa, Hitachi, (southern part), Shimotsuke (southern part), Kotsuke (southern portion), Kai (eastern part), Suruga (eastern part). The shock was felt with a great violence within an area of 300 sq. *ri*, which extended over the five provinces of Sagami (eastern part), Musashi (south-eastern portion), Shimosa (south-western portion), Kazusa and Awa. Within the latter area, houses were damaged, furnitures overturned, etc. Thus in Tokyo, *dozo* (Japanese godowns) had plasters shaken down ; walls were cracked ; tomb stones and *ishidoro* (Japanese stone lanterns) overturned ; furnitures overthrown ; pendulum clocks stopped ; liquids thrown out ; etc. In Yokohama, some houses were damaged. In Aiko District, province of

Sagami, *dozo* were cracked. Along the sea shore of Tsurugi-zaki in the same province the shock was also very strong and some houses were damaged. In Awa, pendulum clocks were stopped, and waters thrown out from vessels which were about $\frac{7}{10}$ full. In the Mota District, province of Kazusa, house walls were cracked, articles overthrown, and liquids thrown out by about 30% from vessels filled with them. In the Nagara District of the same province, people generally ran out of doors, and liquids were thrown out of vessels.

In the Kawachi District, province of Shimotsuke, house walls were cracked, bottles overturned, pendulum clocks stopped. In the Haga District of the same province, pendulum clocks were stopped and liquids thrown out. In the Naka-Koma District, province of Kai, some articles were overturned. This earthquake originated like some other strong ones probably at the southern extremity of the Tokyo Bay. But it was for the first time since the winter of 1884, when the system of the earthquake observation in Japan was organized, that the disturbance extended to such great distances towards North-West. The damage produced, however, was not very severe.

The direction of motion in the meizo-seismal area was as follows: *SE-NW* or *E-W* on the western shore of the Tokyo Bay, *E-W* and *SE-NW* on the eastern, and mostly *N-S* on the northern shore.

Hongo.

Horizontal motion. Duration = 8m. The earthquake began with preliminary tremor, which lasted for about 11s and consisted of quick small vibrations. These latter were already moderatley strong, (max. $2a = 0.8$ mm), being as large as the movements in the earthquake of March 9, 1888.

After the termination of the preliminary tremor, the motion became suddenly great in the two horizontal components, there being five prominent displacements, the first of which was from *S* to *N*, and the second of which was nearly from *E* to *W*. The succeeding vibrations, which were far smaller, were quick in period. After about 20s from the commencement of the earthquake, the superposed ripples disappear-

ed and the vibrations became slow in period. The five principal displacements above referred to were as follows:—

1st displacement:—

$2a = 1.7$ mm, Direction from *S* to *N*, $T_o = 0.41$ s; $V = 13$ mm/s,

$$A = 200 \text{ mm/s.}^2$$

2nd displacement:—

$2a = 2.1$ mm, Direction $S 72^\circ W$, $T_o = 0.64$ s; $V = 10.3$ mm/s,

$$A = 100 \text{ mm/s.}^2$$

3rd displacement:—

$2a = 3.2$ mm, Direction $S 59^\circ E$, $T_o = 0.54$ s; $V = 18.6$ mm/s,

$$A = 220 \text{ mm/s.}^2$$

4th displacement:—

$2a = 6.0$ mm, Direction $S 57^\circ W$, $T_o = 0.58$ s; $V = 32.5$ mm/s,

$$A = 350 \text{ mm/s.}^2$$

5th displacement:—

$2a = 7.2$ mm, Direction $S 48^\circ E$, $T_o = 1.3$ s; $V = 17.4$ mm/s,

$$A = 84 \text{ mm/s.}^2$$

In the earlier part of the earthquake, the vibrations were very irregular and complex and it was not possible to see any definite relation between the $2a$ and T . The measurement in the following table has been taken from the horizontal component after the disappearance of the ripples.

HONGO : HORIZONTAL MOTION.

2a (mm)	T (sec.)	2a (mm)	T (sec.)
4.2	2.0	1.3	1.7
4.0	2.4		
3.1	2.2		
3.0	1.6		
2.6	1.9		
2.4	2.4		
2.2	1.8		
1.9	1.6			0.55 (mean)	1.07 (mean)
1.9	1.5		
1.9	1.7		
1.8	1.2		
1.8	1.6		
1.8	1.9		
1.7	1.5		
1.6	1.9		
1.6	1.9		
1.6	1.7		
1.5	1.1		
1.5	1.7		
1.4	1.1		

Vertical motion. Duration = 220s.

The preliminary tremor lasted for about 9s, during which the maximum motion was 0.3 mm. Then followed two large displacements superposed with irregular ripples: The succeeding vibrations were somewhat smaller but quick in period, so that the character of motion were exactly similar to that of the horizontal. From the 22nd second the vibrations became slower in period.

$$\text{Max. } 2a = 1.0 \text{ mm, } T_0 = 0.96 \text{ s; } V = 3.3 \text{ mm/s, } A = 21.4 \text{ mm/s}^2.$$

The maximum motion occurred 2.4s earlier than the large horizontal vibration; the most active portion of the vertical component also ending 2.4s earlier than the corresponding portion of the horizontal.

In this case, the motion was, unlike that in small earthquakes, not simple and regular, but was irregular and superposed with ripples.

The relation between the 2a and T is given in the following table.—

HONGO ; VERTICAL MOTION.

2a (mm)	T (sec.)	2a (mm)	T (sec)
1.1	0.92		
1.0	0.96		
0.8	1.06		
0.8	0.67		
0.8	0.67		
0.8	0.87	0.38	0.39
0.8	1.06	0.38	0.68
0.75	0.69	0.31	0.33
0.75	0.77	0.31	0.40
0.75	0.58	0.29	0.48
0.75	0.96	0.28	0.48
		0.28	0.39
0.63	0.39	0.13	0.48
0.63	0.77	0.13	0.19
0.63	0.87	0.13	0.34
0.63	0.68		
0.56	0.48		
0.56	0.77		
0.5	0.39		
0.5	0.68		
0.5	0.55		
0.44	0.53		
0.44	0.39		

The average period deduced from 30 vibrations in the end portion was 0.39s.

Eqke No. 155. Feb.18, 1889 ; 6.27.45 a.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 120s.

Direction *SW-NE*.

Max. H.M. 0.2mm.

Area of disturbance. The total land area of disturbance was 1320 sq. *ri*, and extended over the following 10 provinces ; Musashi, Sagami (eastern part, Kazusa western part), Shimosa (western part), Hitachi (south-western portion), Shimotsuke (southern part), Kotsuke (southern part), Shinano (eastern portion), Kai (eastern portion), Suruga north-eastern portion). The motion was generally weak.

Hitotsubashi.

Duration=100s. The motion was almost entirely in the *EW* direction, there being no vertical component.

Max. $2a=0.3\text{mm}$, $T_o=0.65\text{s}$; $V=1.4\text{mm/s}$, $A=14.0\text{mm/s}^2$.

The period remained exactly constant, the average value deduced from 30 vibrations being 0.74s.

Eqke No. 156. Feb. 18, 1889; 7.48.52 a.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 120s.

Direction. *E-W*.

Max. H.M. Small.

The area of disturbance was nearly identical with that of the preceding (*Eqke No. 155*), the motion having been felt *weakly* or *slightly*.

Eqke No. 157. Feb. 18, 1889; 8.2.0 a.m.

Observed as a tremor at the *Cent. Met. Observatory*.

The area of disturbance was limited to the vicinity of Tokyo.

Eqke No. 158. Feb. 18, 1889; 10.10.56 a.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 30s.

Direction. *SE-NW*.

• Max. H.M. Small.

The land area of disturbance was 1050 sq. *ri* and extended more in the *N-S* direction than those of earthquakes Nos. 155 and 156, including the following 8 provinces :—Musashi, Sagami (eastern part), Kai (north-eastern portion), Kotsuke (south-eastern part), Shimotsuke (south-western portion), Hitachi (south-western portion), Shimosa (western part), Kazusa (western portion).

The shock was felt *weakly*.

Eqke No. 159. Feb. 19, 1889; 2.57.43 p.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 15s.

Direction. *N-S*.

Max. H.M. Small.

Character. Gentle.

Eqke No. 160. Feb. 20, 1889 ; 9.19.37 p.m.

Observed as a tremor at the *Cent. Met. Observatory*.

Eqke No. 161. Feb. 21, 1889 ; 5.52.21 a.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 15s.

Direction. *E-W*.

Max. H.M. Small.

Character. Sharp.

Hitotsubashi.

Duration = 25s. A very small earthquake, whose motion was entirely in the *EW* direction, there being no vertical component.

Max. $2a = 0.13\text{mm}$, $T_0 = 0.51\text{s}$; $V = 0.8\text{ mm/s}$, $A = 9.9\text{ mm/s}^2$

The average period, deduced from 21 vibrations in the *EW* component, was 0.62s.

Eqke No. 162. Feb. 21, 1889 ; 8.19.23 a.m.

Observation at the *Cent. Met. Observatory* :—

Duration = 20s.

Direction. *N-S*.

Max. H.M. Small.

Character. Gentle.

Eqke No. 163. Feb. 21, 1889 ; 11.1.4 a.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 30s.

Max. H.M. Very small.

Character. Gentle.

Eqke No. 164. Feb. 21, 1889 ; 9.27.52 p.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 15s.

Direction. *N-S.*

Max. H.M. Small.

Character. Gentle.

Eqke No. 165. Feb. 23, 1889 ; 11.27.21 p.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 13s.

Direction. *N-S.*

Max. H.M. Small.

Character. Gentle.

Eqke No. 166. March 3, 1889 ; 4.35.19 p.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 30s.

Direction. *N-S.*

Max. H.M. 0.2mm (period = 0.6s).

Eqke No. 167. March 4, 1889 ; 7.24.25 a.m.

Observed as a tremor at the *Cent. Met. Observatory.*

Hitotsubashi.

Duration = 80s. This was a small earthquake, whose motion was almost entirely in the *EW* direction, there being no vertical component. The maximum vibration occurred at the commencement, the succeeding vibrations presenting alternations of maximum and minimum groups.

Max. $2a = 0.25$ mm, $T_0 = 0.65$ s ; $V = 1.2$ mm/s, $A = 11.7$ mm/s.²

The average period, deduced from 44 vibrations in the *EW* component, was 0.69s.

Hongo.

Duration=20s. The motion, which was extremely small, occurred equally in the two horizontal directions there being no vertical component.

Eqke No. 168. March 18, 1889 ; 6.41.12 a.m.

Observation at the *Cent. Met. Observatory* :—

Direction. *N-S.*

Max. H.M. Small.

Eqke No. 169. March 21, 1889 ; 6.9.23 p.m.

A tremor observed at the *Cent. Met. Observatory.*

Eqke No. 170. March 26, 1889 ; 2.41.48 p.m.

A tremor observed at the *Cent. Met. Observatory.*

Eqke No. 171. March 28, 1889 ; 1.20.10 a.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 90s.

Direction. *ESE-WNW.*

Max. H.M. 4.1 mm (period=0.6s).

Max. V.M. 0.6 mm (period=0.5s).

Character. Quick.

Remark. The horizontal preliminary tremor lasted for 4s, when the maximum horizontal motion suddenly took place. The vertical motion also became active at the 4th second from the start, its maximum having occurred 4s later than the horizontal maximum.

Hongo.

Horizontal motion. Duration=80s. The motion consisted principally of quick vibrations, which were irregular at first but became regular later on ; there being no prominent movement. The motion was maximum at the commencement and active only during the first 20s, so that the intensity decreased rapidly. The amplitude was greater in the *EW* component ; the motion at the start being principally in the *EW* direction.

Max. $2a=0.7$ mm, $T_o=0.25$ s : $V=8.8$ mm/s, $A=221$ mm/s.²

Another vibration was as follows :—

Max. $2a=0.5$ mm, $T_o=0.21$ s ; $V=7.5$ mm/s, $A=224$ mm/s.²

The average period of the quick vibrations in the earlier part of the earthquake was as follows :—

EW component 0.27s (deduced from 40 vibrations),

NS „ 0.29s („ „ 22 „).

Towards the end the vibrations were slow and had the following average periods :—

EW component 1.2s (deduced from 6 vibrations),

NS „ 0.75s („ „ 46 „).

Vertical motion. Duration = 60s. The motion was maximum at the commencement and remained active during the first 25s. The period was at first quick, but became slow towards the end.

Max. $2a=0.23$ mm, $T_o=0.44$ s ; $V=1.6$ mm/s, $A=23.5$ mm/s.²

The average period was at first 0.36s (deduced from 22 vibrations), but in the end portion 0.65s (deduced from 10 vibrations).

Eqke No. 172. March 28, 1889 ; 10.22.55 a.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 75s.

Direction. *SE-NW*.

Max. H.M. 0.5 mm (period = 0.5s).

Max. V.M. Small.

Character. Gentle.

Remark. The motion was active from the commencement, there being 50 similar vibrations during the first 23s. The vertical motion was very small and lasted for 40s.

Hongo.

Horizontal motion. Duration = 100s.

The motion began very gently with small slow vibrations.

Max. $2a=0.8$ mm, $T_o=0.69$ s ; $V=3.6$ mm/s, $A=33.2$ mm/s.²

The average period was as follows :—

EW component 0.75s (deduced from 48 vibrations),

NS „ 1.0s („ „ 36 „).

Vertical motion. Duration = 40s. The motion consisted of small slow vibrations.

Max. $2a = 0.2\text{mm}$, $T_0 = 0.93\text{s}$; $V = 0.7\text{mm/s}$, $A = 4.6\text{mm/s}^2$

The average period deduced from 17 vibrations was 0.66s.

Eqke No. 173. March 28, 1889 ; 7.18.23 p.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 20s.

Direction. *E-W*.

Max. H.M. 0.2 mm (period = 0.2s).

Character. Quick.

Remark. The preliminary tremor lasted for 5s, when suddenly the maximum movement took place, the motion remaining active for the next 5s.

Eqke No. 174. March 31, 1889 ; 6.42.15 a.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 240s.

Direction. *SES-NWN*.

Max. H.M. 3.8mm (period = 2.5s).

Max. V.M. 0.2mm (period = 0.6s).

Character. Gentle.

Remark. The motion was at first very small, the horizontal movement becoming active at the 5th second and reaching the maximum at the 25th second. The vertical maximum occurred at the 15th second, the motion lasting altogether for about 25s.

Hongo.

Horizontal motion. Duration = 200s. The motion consisted of slow undulations, superposed with some small ripples.

Max. $2a = 1.2\text{mm}$, $T_0 = 1.13\text{s}$; $V = 3.3\text{mm/s}$, $A = 190\text{mm/s}^2$.

The average period was as follows :—

EW component 1.24s (deduced from 16 vibrations),

NS „ 1.12s („ „ 40 „).

Vertical motion. Duration = 65s. The motion was at first irregular and there was no prominently large movement.

Max. $2a = 1.4\text{mm}$, $T_o = 0.82\text{s}$; $V = 5.4\text{mm/s}$, $A = 41.0\text{mm/s}^2$

The quick vibrations at the commencement had an average period of 0.12s. Towards the end the average period was 0.83s.

Eqke No. 175. March 31, 1889; 8.13.3 a.m.

A tremor observed at the *Cent. Met. Observatory*.

Eqke No. 176. March 31, 1889; 5.59.42 p.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 120s.

Direction. *SW-NE*.

Max. H.M. 1.2mm (period = 0.7s).

Max. V.M. Very small.

Character. Gentle.

Remark. The earthquake began with very small movements, the maximum horizontal motion occurring at the 30th second. For the next 60 seconds the motion was more or less active. The vertical motion lasted for 50s.

Hongo.

Horizontal motion. Duration = 240s. The motion, which began very gradually, was more in the *EW* direction and consisted of slow vibrations. The following well defined movement took place a few seconds from the commencement :—

Max. $2a = 0.6\text{mm}$, $T = 1.43\text{s}$; $V = 1.3\text{mm/s}$, $A = 5.8\text{mm/s}^2$

For the next 7.8s during which the motion was irregular, small ripples were superposed on slow vibrations; the average period being 0.49s. The motion then became gradually regular and increased in amplitude, till the following maximum took place at the 80th second :—

Max. $2a = 1.1\text{mm}$, $T_o = 2.1\text{s}$; $V = 1.6\text{mm/s}$, $A = 4.9\text{mm/s}^2$

The vibrations remained nearly constant for a considerable length of time.

The average period of vibration was as follows :—

EW component 2.32s (deduced from 24 vibrations),

NS „ 1.19s („ „ 58 „).

Vertical motion. Duration = 60s. The motion was very small and consisted of slow vibrations.

Max. $2a = 0.01$ mm, $T_0 = 0.51$ s ; $V = \text{small}$, $A = \text{small}$.

The average period deduced from 13 vibrations was 0.54s.

Eqke No. 177. April 3, 1889 ; 4.27.21 p.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 90s.

Direction. *SE-NW*.

Max. H.M. 1.5mm (period = 0.7s).

Max. V.M. 0.2mm (period = 0.3s).

Character. Quick.

Remark. The preliminary tremor lasted for 3s, when the maximum horizontal motion suddenly took place, the movements being active for the next 20s. The maximum of the vertical motion, which was already well pronounced at the commencement, took place at the 2nd second, the motion being active for the next 10s. The duration of the vertical component was about 32s.

Hongo.

Horizontal motion. Duration = 80s. The motion, which was greater in the *EW* than in the *NS* direction, consisted at first of small quick vibrations. Towards the end the movements became regular and slow.

Max. $2a = 0.3$ mm, $T_0 = 0.26$ s ; $V = 3.6$ mm/s, $A = 87.5$ mm/s.²

In the *EW* component, the average period of the earlier quick vibrations was 0.19s (deduced from 70 vibrations), while that of the slow undulations in the end portion was 1.6s (deduced from 6 vibrations). In the *NS* component, the superposed ripples were insignificant, the average period of the slow movements, deduced from 34 vibrations, being 0.79s.

Vertical motion. Duration = 40s. The motion was maximum at the commencement.

Max. $2a = 0.06$ mm, $T_o = 0.32$ s; $V =$ small, $A =$ small.

The average period was at first 0.27s (deduced from 13 vibrations), but towards the end 0.55s (deduced from 10 vibrations).

Eqke No. 178. April 3, 1889; 4.40.51 p.m.

A tremor observed at the *Cent. Met. Observatory.*

Eqke No. 179. April 6, 1889; 7.40.13 a.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 50s.

Direction. *SW-NE.*

Max. H.M. 0.3mm (period = 0.5s).

Max. V.M. Very small.

Character. Quick.

Hongo.

Horizontal motion. Duration = 25s.

Max. $2a = 0.26$ mm, $T_o = 0.49$ s; $V = 1.7$ mm/s, $A = 21.4$ mm/s².

The average period, deduced from 4 vibrations in the *NS* component, was 0.6s.

Vertical motion. Duration = 20s. The motion was very small. The average period, deduced from 11 vibrations, was about 0.23s.

Eqke No. 180. April 8, 1889; 0.48.0 p.m.

A tremor observed at the *Cent. Met. Observatory.*

Eqke No. 181. April 14, 1889; 5.22.54 a.m.

A tremor observed at the *Cent. Met. Observatory.*

Eqke No. 182. April 18, 1889; 2.7.41 p.m.

Observation at the *Cent. Met. Observatory* :—

Duration. —

Direction. *ESE-WNW.*

EW component 0.48s (deduced from 31 vibrations),
NS „ 1.15s („ „ 29 „).

After the preliminary tremor, the movements became very large and slow, the maximum being the following :—

Max. $2a = 17$ mm, $T_o = 2.8$ s ; $V = 19.0$ mm/s, $A = 42.7$ mm/s.²

Other waves had still longer periods. The average period, deduced from 11 undulations in the end part of the *EW* component, was 6.5s.

Vertical motion. Duration = 6m. The motion consisted of extremely small slow undulations. The preliminary tremor lasted for about 100s, when the following maximum took place :—

Max. $2a = 1.5$ mm, $T_o = 0.31$ s ; $V = 15.2$ mm/s, $A = 308$ mm/s.²

The maximum was single and well defined, all the rest being small and irregular.

Eqke No. 183. April 18, 1889 ; 2.54.11 p.m.

A tremor observed at the *Cent. Met. Observatory*.

The earthquake was also felt at the Miura District, province of Sagami.

Eqke No. 184. April 18, 1889 ; 3.39.8 p.m.

Observation at the *Cent. Met. Observatory* :—

Direction. *SE-NW*.

Max. H.M. 0.3mm (period = 0.9s).

Character. Gentle.

Area of disturbance. The land area of disturbance was 1410 sq. *ri* and extended over the following 11 provinces :— Izu, Shimoso, Sagami, Musashi, Kazusa, Awa, Suruga (eastern part), Kai (eastern part), Kotsuke (south-eastern portion), Shimotsuke (southern portion), Hitachi (southern portion). The intensity was *weak* or *slight*, the motion being generally slow and horizontal. In Ōshima, the shock was felt very slightly.

Hongo.

Horizontal motion. Duration = 60s. The motion, which occurred

equally in the two horizontal directions, consisted of small gentle vibrations.

Max. $2a = 0.1$ mm.

The average period was as follows :—

EW component, 0.48s (deduced from 21 vibrations),

NS „ 0.68s („ „ 21 „).

Vertical motion. Duration = 25s.

Max. $2a = 0.05$ mm, $T_0 = 0.39$ s ; $V = 0.4$ mm/s, $A = 6.5$ mm/s.²

The average period deduced from 23 vibrations was 0.45s.

Eqke No. 185. April 18, 1889 ; 4.0.1 p.m.

A tremor observed at the *Cent. Met. Observatory.*

Eqke No. 186. April 19, 1889 ; 0.18.46 a.m.

A tremor observed at the *Cent. Met. Observatory.*

Eqke No. 187. April 19, 1889 ; 2.29.19 a.m.

A tremor observed at the *Cent. Met. Observatory.*

Eqke No. 188. April 19, 1889 ; 3.0.27 p.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 50s.

Direction. *SW-NE.*

Max.H.M. 0.2 mm (period 0.6s).

Character. Gentle.

Eqke No. 189. April 19, 1889 ; 5.50.39 p.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 90s.

Direction. *E-W.*

Max.H.M. 0.2mm (period = 0.6s).

Max.V.M. Very small.

Character. Gentle.

Eqke No. 190. April 19, 1889 ; 10.53.55 p.m.

Observed as a tremor at the *Cent. Met. Observatory.*

Hongo.

Duration=50s. This was a very small earthquake whose motion consisted of gentle vibrations, chiefly in the *NS* direction.

Max. $2a = 0.2$ mm, $T_o = 1.1$ s; $V = 0.6$ mm/s, $A = 3.3$ mm/s.²

The average period, deduced from 13 vibrations in the *NS* component, was 1.0s.

Eqke No. 191. April 20, 1889; 4.50.33 p.m.

A tremor observed at the *Cent. Met. Observatory.*

Eqke No. 192. April 28, 1889; 3.7.43 a.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 30s.

Direction. *E-W.*

Max. H.M. Small.

Max. V.M. Very small.

Character. Gentle.

Hongo.

Duration = 60s.

Max. $2a = 0.2$ mm, $T_c = 0.67$ s; $V = 0.9$ mm/s, $A = 8.8$ mm/s.²

Eqke No. 193. April 29, 1889; 1.56.28 a.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 20s.

Direction. *E-W.*

Max. H.M. Small.

Max. V.M. Very small.

Eqke No. 194. May 6, 1889; 11.41.41 p.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 60s.

Direction. *NEN-SWS.*

Max. H.M. 0.4 mm (period = 0.5s).
 Max. V.M. Very small.
 Character. Sharp.

Hongo.

Horizontal motion. Duration = 120s. The max. $2a$ (= 0.4 mm) occurred at the commencement, the subsequent motion consisting of extremely small ripples superposed on slow undulations.

The period of the ripples, which existed chiefly in the *EW* direction, was 0.21s (deduced from 29 vibrations). The average period of the slow undulations was as follows:—

EW component . . . 1.3s (deduced from 11 vibrations),
NS „ . . . 1.1s („ „ 38 „).

Vertical motion. The motion was very small.

Eqke No. 195. May 8, 1889 ; 5.534 a.m.

Observation at the *Cent. Met. Observatory* :—
 Duration. 30s.
 Direction. *N-S*.
 Max. H.M. Small.
 Max. V.M. Very small.
 Character. Gentle.

Eqke No. 196. May 8, 1889 ; 0.24.7 p.m.

A tremor observed at the *Cent. Met. Observatory*.

Eqke No. 197. May 12, 1889 ; 10.42.11 a.m.

Observation at the *Cent. Met. Observatory* :—
 Duration. 120s.
 Direction. *SES-NWN*.
 Max. H.M. 0.6mm (period = 2.0s).
 Character. Gentle.

Area of disturbance. The earthquake was the greatest which happened since the winter of 1884, and which originated in central Japan, the

disturbance extending over the whole tract between Shimotsuke and Musashi on the north-east, and Bitchu, Awa and Sanuki on the west. The total land area of disturbance was 4800 sq. *ri* and included the following 37 provinces:—Mino, Owari, Ise, Mikawa, Totomi, Ōmi, Iga, Yamashiro, Wakasa, Echizen, Hida, Suruga, Kai, Izu, Sagami, Musashi, Shimosa (northern portion, Shimotsuke south-western portion), Kotsuke (southern portion), Shinano (southern part), Etchui (southern part), Shima, Kii, Yamato, Izumi, Kawachi, Settsu, Tanba, Tango, Awaji, Tajima (eastern portion), Harima (eastern part), Bizen, Bitchu (eastern portion), Sanuki (eastern part), Awa (eastern part). The area of *strong* motion was 1500 sq. *ri* and included the following provinces:—Mino (southern part), Owari, Mikawa, Totomi, Suruga (western portion), Shinano (south-western portion), Ise (northern part), Iga (northern part), Ōmi, Yamashiro (eastern part), Tanba (eastern portion), Wakasa (eastern part), Echizen (southern part), Hida (southern portion); the shock being especially severe in the area of 220 sq. *ri*, which included Mino (southern part), Owari (northern part). The area of *weak* motion, within which the shock was distinctly felt, was 1630 sq. *ri* and extended over Echizen (northern portion), Kaga (southern part), Hida (central part), Shinano (central portion), Suruga (central part), Kai (western part), Shima, Ise (southern portion), Iga (southern portion), Kii (eastern portion), Yamato, Kawachi, Izumi (eastern part), Yamashiro (western portion), Settsu (eastern part), Tanba (central part), Wakasa (western portion), Tango (eastern portion). Finally the area of *slight* motion, within which the shock was just sufficiently intense to be felt, was 1670 sq. *ri* and extended over Kaga (northern part), Etchui (southern part), Hida (northern portion), Shinano (northern part), Kotsuke (southern portion), Shimotsuke (south-western portion), Shimosa (northern portion), Musashi, Sagami, Izu, Suruga (eastern portion), Kai (eastern portion), Kii (western part), Izumi (western part), Awaji, Settsu (western portion), Tanba (western portion), Tango (western part), Tajima (eastern portion), Harima (eastern part), Bizen, Bitchu (eastern portion), Sanuki (eastern part), Awa (eastern part). In the meioseismal area the motion was so violent that some damage was

produced. Thus in the vicinity of Gifu, the Nagara-gawa embankment was cracked for some length at a locality called Jōmon; bottles and earthen wares were thrown down from shelves; pendulum clocks stopped, etc., According to the observation at Gifu Meteorological Observatory, the duration of the earthquake was 2m 30s; the preliminary tremor lasted for 3s, when the motion became strong; at the 5th second, the *NS* component indicated a movement of about 15mm; immediately thereafter strong *EW* component motion also set in and threw the *steady masses* of the seismograph out of their position, so that the subsequent movements could not be measured. The earthquake was much stronger than that of July 7, 1888. The damage produced in some of the Districts of the province of Mino was as follows:— (*Haguri District*) waters in puddy fields were rendered turbid in consequence of the shakings; (*Anpachi District*) liquids were thrown out, suspended lamps oscillated considerably, and pendulum clocks facing *S* or *N* were stopped; (*Motosu District*) some vessels were overturned; (*Mugi District*) walls of houses, whose foundation was not solid, were cracked, and liquids were thrown out; (*Kani District*) some pendulum clocks facing *N* stopped; (*Kamo District*) some pendulum clocks stopped. In Aichi District, in the province of Owari, pendulum clocks facing *N* or *S* were stopped.

Hongo.

Duration = 120s. The earthquake, which began very gently, consisted of regular slow vibrations; there being no vertical motion.

Max. $2a = 0.5$ mm, $T_0 = 1.16$ s; $V = 1.6$ mm/s, $A = 8.2$ mm/s.²

The average period of vibration was as follows:—

EW component 1.24s (deduced from 10 vibrations),
NS „ 1.14s („ „ 53 „).

In earthquakes of this character, the amplitude remains, with some alternations of maximum and minimum groups, nearly constant for a considerable length of time and does not decrease so rapidly as in those earthquakes, whose motion is irregular and is superposed with ripples or entirely made up of these latter.

Eqke No. 198. May 17, 1889: 6.39.15 a.m.

A tremor observed at the *Cent. Met. Observatory*.

Eqke No. 199. May 17, 1889 ; 8.34.25 a.m.

A tremor observed at the *Cent. Met. Observatory*.

Eqke No. 200. May 17, 1889 ; 9.20.35 a.m.

A tremor observed at the *Cent. Met. Observatory*.

Eqke No. 201. May 17, 1889 ; 9.39.37 a.m.

A tremor observed at the *Cent. Met. Observatory*.

Eqke No. 202. May 17, 1889 ; 1.46.32 p.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 30s.

Max. H.M. Small.

Hongo.

The motion was very small.

Eqke No. 203. May 20, 1889 ; 0.23.30 p.m.

A tremor observed at the *Cent. Met. Observatory*.

Eqke No. 204. May 27, 1889 ; 6.22.56 p.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 120s.

Direction. *E-W*.

Max. H.M. Very small.

Eqke No. 205. May 28, 1889 ; 5.26.22 a.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 15s.

Direction. *E-W*.

Max. H.M. Small.

Eqke No. 206. May 28, 1889 ; 7.4.55 a.m.

Hongo.

The motion was very small.

Eqke No. 207. May 30, 1889; 10.27.22 p.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 120s.

Direction. *SE-NW*.

Max. H.M. 0.4mm (period = 0.8s).

Character. Quick.

Hongo.

Horizontal motion. Duration = 180s. The preliminary tremor, which consisted of very small and gentle movements, lasted for 60s, when 3 large vibrations suddenly took place. The subsequent motion was small and regular.

Max. $2a = 0.56\text{mm}$, $T_o = 1.12\text{s}$; $V = 1.6\text{ mm/s}$, $A = 8.8\text{ mm/s}^2$

The average period, deduced from 20 vibrations in the *NS* component, was 1.13s. The motion was much larger in the *NS* than in the *EW* direction.

Vertical motion. Duration = 90s.

Max. $2a = 0.06\text{ mm}$, $T_o = 0.32\text{s}$; $V = 0.6\text{ mm/s}$, $A = 11.6\text{ mm/s}^2$

Eqke No. 208. June 1, 1889; 6.15.21 p.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 25s.

Direction. *E-W*.

Max. H.M. 0.2 mm (period = 0.5s).

Character. Gentle.

Hongo.

Duration = 50s. This was a very small earthquake, whose motion was nearly equal in the two horizontal directions.

Eqke No. 209. June 3, 1889; 1.51.30 p.m.

Observed as a tremor at the *Cent. Met. Observatory*.

Hongo.

The motion was very small.

Eqke No. 210. June 3, 1889 ; 2 p.m.

Hongo.

The motion was very small.

Eqke No. 211. June 14, 1889 ; 0.26.41 p.m.

Observed as a tremor at the *Cent. Met. Observatory.*

Eqke No. 212. June 15, 1889 ; 10.10.2 a.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 50s.

Max. H.M. Small.

Character. Gentle.

Hongo.

Duration = 30s. This was a small earthquake, whose motion was nearly equal in the two horizontal directions and consisted of regular slow vibrations ; there being no vertical component. The maximum occurred at the commencement.

Max. $2a = 0.14$ mm, $T_o = 0.84$ s ; $V = 0.5$ mm/s, $A = 3.9$ mm/s.²

The average period, deduced from 17 vibrations in the *NS* component, was 0.88s

Eqke No. 213. June 16, 1889 ; 2.31.24 p.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 30s.

Direction. *SE-NW.*

Max. H.M. Small.

Character. Quick.

Hongo.

Horizontal motion. Duration = 15s.

Max $2a = 0.1$ mm.

The earlier portion of the *EW* component consisted of ripples, whose average period was about 0.21s.

Vertical motion. Small traces of vertical motion occurred only for a few seconds.

Eqke No. 214. June 20, 1889 : 9.51.10 p.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 90s.

Direction. *SE-NW*.

Max H.M. 0.5mm (period = 0.6s).

Max V.M. Small.

Character. Quick.

Hongo.

Horizontal motion. Duration = 90s. In each horizontal component, the motion, which consisted at first of very small ripples, became gradually regular.

Max. $2a = 0.1$ mm, $T_o = 0.56$ s ; $V = 0.6$ mm/s, $A = 6.3$ mm/s².

The average period of the ripples was as follows :—

EW component 0.20s (deduced from 19 vibrations),

NS „ 0.20s („ „ 18 „).

The average period of the regular waves in the end portion was 0.55s (deduced from 51 vibrations in the *EW* component).

Vertical motion. Duration = 70s. The motion, which was maximum at the commencement, consisted of a series of small quick vibrations decreasing gradually.

Max. $2a = 0.06$ mm, $T_o = 0.19$ s ; $V = 1.0$ mm/s, $A = 33$ mm/s².

Towards the end, the vibrations became slow ; the average period deduced from 32 vibrations being 0.57s.

Eqke No. 215. June 27, 1889 ; 7.9.17 a.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 60s.

Direction. *E-W*.

Max. H.M. 0.5mm (period = 2.5s).

Character. Gentle.

Hongo.

Duration = 90s. The motion, which occurred equally in the two horizontal components consisted of small slow vibrations and gradually attained the maximum, thence again very gradually diminishing. There was no vertical motion.

Max. $2a = 0.2$ mm, $T_0 = 1.14$ s; $V = 0.6$ mm/s, $A = 3.2$ mm/s.²

The average period of vibration was as follows: —

EW component 1.44s (deduced from 8 vibrations),

NS „ 1.19s („ „ 36 „).

Eqke No. 216. July 3, 1889; 5.39.58 p.m.

Observation at the *Cent. Met. Observatory*: —

Duration. 40s.

Direction. *E-W*.

Max. H.M. 0.3mm (period = 0.5s).

Max. V.M. Very small.

Character. Quick.

Hongo.

Duration = 30s. The motion, which was almost entirely in the *EW* direction, began with the maximum vibration, the subsequent portion consisting of extremely small movements. Towards the end, the motion became regular. There was no vertical motion.

Max. $2a = 0.24$ mm.

In the *EW* component, the average period of the earlier ripples, deduced from 19 vibrations, was 0.20s, while that deduced from 13 vibrations in the end portion was 0.43s.

Eqke No. 217. July 5, 1889; 6.22.31 p.m.

A tremor observed at the *Cent. Met. Observatory*.

Eqke No. 218. July 5, 1889; 8.57.9 p.m.

A tremor observed at the *Cent. Met. Observatory*.

Eqke No. 219. July 18, 1889; 10.33.18 p.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 35s.

Direction. *N-S*.

Max. H.M. Small.

Character. Sharp.

Hongo.

Duration=30s. The motion consisted of small quick vibrations. The vertical motion was very small.

Max. $2a = 0.1$ mm, $T_o = 0.20$ s; $V = 1.6$ mm/s, $A = 49.3$ mm/s.²

The average period of vibration was as follows :—

EW component 0.19s (deduced from 27 vibrations),

NS „ 0.17s („ „ 38 „).

The average period, deduced from 14 vibrations. In the end portion of the *EW* component, was 0.28s.

Eqke No. 220. July 30, 1889; 2.3.40 a.m.

Observation at the *Cent. Met. Observatory* :—

Duration. 10s.

Direction. *E-W*.

Max. H.M. Small.

Character. Gentle.

Hongo.

Duration=15s. This was a very small earthquake of the same character as the preceding. The vertical motion was extremely small.

Max. $2a = 0.1$ mm, $T_o = 0.25$ s; $V = 1.3$ mm/s, $A = 31.6$ mm/s.²

The average period was in the earlier part 0.17s (deduced from 10 vibrations), and towards the end 0.44s (deduced from 6 vibrations).

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ERRATA.

- Page 44, line 3, *for* Hitotsubashi *read* Hongo.
„ 45, between line 5 and line 6, *insert*
Hitotsubashi.
„ „ line 10, *for* April 5, 1881 *read* April
5, 1888 (No. 65).