Seismograms Showing no Preliminary Tremor.

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1. ***Introduction.*** The examination of the horizontal pendulum diagrams of the Japan earthquake of Jan. 21, 1906, which originated off the south-eastern coast of the Main Island, has accidentally revealed that some earthquake motion indicates no preliminary tremor when observed at places situated in certain directions relative to the seismic origin; the earthquake of Feb. 6, 1907, also indicating the same fact. Studies in this connection may throw much light on the nature of the vibrations composing the initial part of the *macro-seismic* earthquake motion; the present note giving a short account of the observations of the earthquake of Jan. 21, 1906. I have here to express my thanks to Mr. N. Shimono, Director of the Ōsaka Meteorological Observatory, for his valuable suggestions and assistance given me in connection with the investigation of the earthquake in question.

2. ***Isoseismals.*** (Fig. 1.) The earthquake was felt as a slight or moderate shock over a considerable area, which extended from the south-eastern portion of Hokkaido on the north-east to the strait between the islands of Shikoku and Kyushu on the south-west; the boundary of this area, or the isoseismal ***I***, being symmetrical with respect to a line, which is normal to the Japan arc and connects the cape Inuboé (province of Shimosa) with the

southern end of the Sado island. The isoseismal line ***II*** includes the area within which the shock was *strongly* felt.

The earthquake was recorded by Omori Horizontal Pendulums at the different stations in Japan and also at the Meteorological Observatory of Zikawei, near Shanghai.

3. *Position of the Origin.* The approximate position of the earthquake origin may be inferred from the seismograms obtained at Tokyo, Mount Tsukuba, Mito, and Miyako (province of Rikuchu), where the preliminary tremor was clearly observed, as follows.

Place.	Duration of 1st Prel. Tremor $=y$.	Epicentral Distance (*Calculated*) $=x$
Tōkyo	43 *sec.*	350 *km*
Mt. Tsukuba	43	350
Mito	47	380
Miyako	78	610

The epicentral distances given in the above table have been calculated by the formula*

$$x^{km}=7.27\ y^{sec.}+38^{km}.$$

The 4 circles drawn about Tokyo, Mt. Tsukuba, Mito, and Miyako, as centres with the corresponding calculated values of the epicentral distances for the radii, meet as shown in Fig. 1 at points which are close to one another. The approximate position of the earthquake origin thus determined is

$$\varphi=34^\circ\ 23'\text{N}, \qquad \lambda=143^\circ\ 26'\text{E};$$

* The *Publications*, No. 13.

the actual arcual distances from the epicentre, the time* ($=t_1$) of earthquake occurrence, and the duration ($=y$) of the preliminary tremor, for the different stations being as follows.†

Place.	Epicentral Distance $=x$.	Time of occurrence $=t_1$	Duration of Prel. Tremor $=y$
Tōkyo	3° 17′=365 *km*	10^h 50^w 31^s P.M.	43 *sec.*
Mt. Tsukuba ...	3 18 =367	10 51 15	43
Mito	3 09 =350	10 50 33	47
Mizusawa	5 06 =567	10 51 45	67
Miyako	5 23 =598	10 52 44 (?)	78
Ishinomaki	4 23 =487	———	
Osaka	6 32 =726	10 50 28	0
Kyōto	6 21 =705	———	0
Kōbe	6 49 =758	10 50 30	0
Tadotsu	8 00 =889	10 50 23	0
Shanghai	18 57 =2106	10 52 15	141
Taihoku	21 10 =2352	10 53 20	180
Taichū	22 15 =2472	10 52 12 (?)	177
Hōkoto	23 27 =2606	10 51 15 (?)	202
Manila	28 20 =3148	10 54 23	281 (?)

4. *Character of the Seismograms.* The seismograms at the different stations are shown in Figs. 2—15, as follows.

* The times are given in the 1st Normal Japan Time, or that of longitude 135° E.

† All the observation made with Omori Hor. Pendulum, except that at Manila which was made with Vicentini Seismograph.

No. of Fig.	Station.	Component.	Multiplication.	Pendulum Period.
2	Ōsaka	EW	20	27 *sec.*
3	„ (slow time rate)...	„	10	30
4	Kyōto	„	20	30
5	Kōbe	NS	20	25
6	Ishinomaki	EW	11	25
7	Tōkyo (Hitotsubashi)	„	10	24
8	„ (Hongō)	„	120	26.5
9	„ „	NS	20	48.5
10	„ „	EW	15	61.5
11	„ „	Vertical	30	2.0
12	„ „	„	12	4.5
13	Taihoku (Formosa) ...	EW	10	23
14	Mito	„	20	28.8
15	Miyako	„	120	18

From Figs. 2—15, it will be observed that the seismograms obtained at Tōkyo, Mito, Miyako, Ishinomaki, and Taihoku,* indicates the preliminary tremor in the usual way, while those obtained at Ōsaka (EW) and Kyōto (EW) has no preliminary tremor at all. In the Kōbe seismogram (NS), the motion was quite large at the very commencement as was the case with the two last-mentioned places; there being, however, an ill-defined indication of the preliminary tremor.

I give next a short description of the seismograms obtained at the three stations of Ōsaka, Kōbe, and Taihoku; a, $2a$, and

* The seismograms obtained at Mt. Tsukuba, Mizusawa, Shanghai, Taichu, Hōkoto, etc. also indicated the preliminary tremor.

T denoting as usual the amplitude, double-amplitude, and the complete period of vibration, respectively.

Osaka. (Fig. 2.) EW component (Multiplication = 20). Natural oscillation period of the horizontal pendulum=27 sec. The earthquake began quite suddenly with a large quick displacement of 2.9 mm, towards W, followed by a counter motion of 4.9 mm, towards E, this latter being the absolute maximum. The vibrations were active for $2^m\ 20^s$, being composed of the following 3 sets:—

$T=$ 3.7 sec. (larger vibrations),
$T=$ 5.7 „ (smaller „).
$T=27.0$ „ $2a=6.5$ mm (pend. oscillations).

The motion was distinct for further $5^m\ 15^s$:—$T=4.9$ sec.

The diagram furnished by a horizontal pendulum apparatus, whose recording drum rotated once in 24 hours, (Fig. 3), also indicated no preliminary tremor.

Kobe. (Fig. 4.) NS component (Multiplication=20). Natural oscillation period of the horizontal pendulum=25 sec. The earthquake began suddenly with a large vibration, of $T=36$ sec. whose two displacements were as follows:—

1st ..... $a=1.3$ mm, towards N,
2nd.....$2a=1.7$ „ , „ S;

the latter being the maximum of this sort of motion.

The motion was most active for the first $3^m\ 15^s$ and consisted of the following 3 sets of vibrations:—

$T=$ 3.1 sec.
$T=11.1$ sec., $2a=2.1$ mm (this max. occurred 38 sec. after the commencement).
$T=24.5$ sec., $2a=3.3$ mm (pend. oscil.)

Thereafter the motion gradually diminished, the movements being as follows:—

$$\begin{cases} T=11.3 \text{ sec.}, & 2a=0.58 \text{ mm} \\ T=4.0 \text{ ,, (?)}, & 2a=\text{small.} \end{cases}$$

Towards the end:—T=11.1 sec.

Taihoku. (Fig. 13.) EW Component (Multiplication=10). Natural oscillation period of the horizontal pendulum=23 sec.

The preliminary tremor lasted $3^m\ 0^s$, the movements at the very commencement being as follows:—

1st ..... $a=0.11$ mm, towards W;
2nd.....$2a=0.19$,, , ,, E.

The average periods were:—$T=4.0$ sec., $T=2.1$ sec.

The principal portion lasted $6^m\ 55^s$, the movements at the commencement being as follows:—

$$\begin{cases} \text{1st} \ldots\ldots\ a=0.65 \text{ mm, towards W;} \\ \text{2nd}\ldots\ldots 2a=2.55 \text{ ,, , ,, E;} \\ \text{3rd}\ldots\ldots 2a=2.40 \text{ ,, , ,, W.} \end{cases}$$

The subsequent motion was much smaller.

5. *Vibration at the Commencement of the Earthquake.*

(i) *Observations at Ōsaka, Kōbe, Kyōto and Tadotsu.* The 1st vibration of the earthquake motion recorded at the 4 stations of Ōsaka, Kōbe, Kyōto, and Tadotsu, which are situated westwards from the origin, and where the preliminary tremor was entirely absent or unduly large, was as follows:—

Station.	1st Displacement.	2nd Displacement.	Remarks.
Ōsaka (EW).	2.83 mm, towards W.	4.83 mm, towards E.	Quick vib. This was the abs. max.
Kōbe (NS).	1.23 ,, N.	1.73 ,, S.	Quick vibration.
Kyōto (EW)	1.75 ,, W.	2.68 ,, E.	Slow vib. mixed with quick movements.
Tadotsu (EW).	0.90 ,, W.	2.00 ,, E.	Slow vibration.

Combining the observations at Ōsaka and Kōbe, which are near to each other, we find the following resultant motion:—

1st displacement..... a=3.08 mm, towards N 67° W.
2nd „ ..... $2a$=5.14 „ , „ S 71° E.

As the earthquake origin lies to the S 80° E of Ōsaka the initial vibration may be regarded as due to the *longitudinal wave*, and took place in a direction parallel to the line joining the places of observation with the centre of disturbance ; the 1st displacement being directed away from the latter. The initial displacement in the E W component at Kyōto and Tadotsu was also directed towards W. It may be here noted that some microseismographs with a large multiplication ratio and a short natural oscillation period, say, of 2 or 3 seconds, are, on the occasion of a sharp local shock or large earthquake, usually thrown at once into big proper oscillations, thereby indicating apparently or *diagrammatically* the maxmium movement at the commencement. With the observations at Ōsaka and Kōbe, however, the movements recorded were really those of the ground, their periods being the same at the two places, namely, 3.7 and 3.6 sec., and quite different from the natural oscillation periods of the horizontal pendulums, which were 27 and 25 sec. respectively.

(ii) *Observation at Tōkyo.* The observation at Tōkyo, where the preliminary tremor, was clearly indicated is also very interesting, as it gives the directions of vibrations at the very commencement of the motion, and of the principal portion. Taking suitably the mean value of the EW component motion, we find:—

1st displacement at the commencement of the preliminary tremor.....a=0.60 mm, towards W ;

the simultaneous NS and vertical components being as follows:—

$$\begin{cases} a = 1.05 \text{ mm, towards S,} \\ a = 0.54 \quad \text{,, , downwards.} \end{cases}$$

These give for the resultant horizontal motion the following:—

initial (prel. tremor) displacement.....$a = 1.2$ mm, towards S 30° W.

The counter horizontal motion was:—

$2a = 3.2$ mm, towards N 22° E.

Taking the mean from the 1st and the counter displacements, we find:—

direction of the initial vibration.....S 26° W—N 26° E.

As now the origin of the earthquake was to the S 65° E of Tōkyo, it will be observed that the direction of motion of the vibration at the commencement of the preliminary tremor was exactly at right angles to the line joining Tōkyo with the origin; that is to say, the preliminary tremor *in this particular instance* belonged to the *transverse wave.*

Turning now our attention to the *principal portion,* we obtain the following mean result for the 1st displacement of the large vibration at the commencement:—

1st displacement.....$a = 9.9$ mm, towards N58°W.

The counter EW component motion was 13 mm towards E, the two displacements of the vertical motion being respectively $a = 2.3$ mm downwards, and $2a = 3.8$ mm upwards. The NS component pointer, however, unfortunately went out of the smoked paper and did not record the 2nd displacement and the subsequent movements. It will be observed that the 1st displacement of the principal portion was nearly parallel to the line joining the

earthquake origin with Tōkyo, thus belonging to the *longitudinal wave.*

(iii) *EW Component Observations at Mito, Ishinomaki and Miyako.* The seismogram at Mito, which is situated about 100 km to the NW of Tōkyo, was similar in character to those obtained at the latter place. Thus we have:—

Mito (EW)
- 1st displacement at the commencement of the preliminary tremor=0.41 mm, towards W;
- 1st displacement (a) at the commencement of the principal portion=5.4 mm, towards W.
- 2nd displacement ($2a$), or the counter motion of the preceding=11.8 mm, towards E.

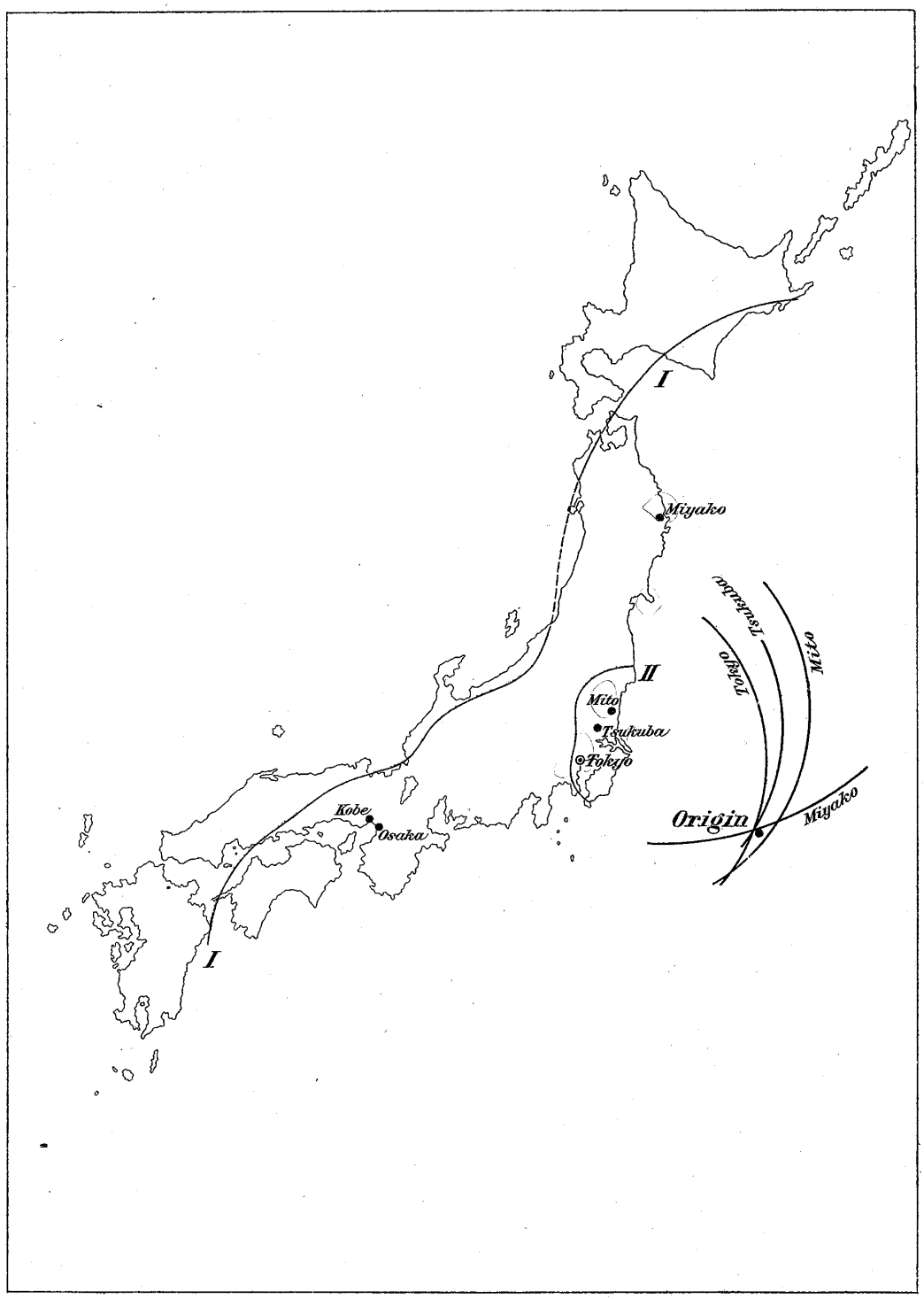
The directions of the movements at the commencement of the EW component principal portion obtained at Ishinomaki and Miyako, both situated in the north-eastern part of the Main Island, were the same as at Tōkyo, being directed towards W and towards E respectively.

6. *Transverse and Longitudinal Vibrations.* By comparing the observation at Tōkyo with those at Ōsaka and Kōbe, we arrive at the conclusion that the first vibrations in the preliminary tremor registered in the former place were due to the *transverse wave*, while the large principal vibrations at the very commencement of the earthquake motion registered at the two latter places (as well as Kyōto and Tadotsu) were due to the *longitudinal wave.* To explain these peculiar relations, we may suppose that the preliminary tremor consisted, from some cause, mainly of the transverse vibrations in a nearly N—S direction. Such movements would give the preliminary tremor at Tōkyo in nearly the N—S direction, but would be overtaken, along the path towards Ōsaka and Kōbe, by the longitudinal wave, whose

propagation velocity is greater than that of the transverse wave; the result being that at the last mentioned places we got first the large vibrations constituting the principal portion, due to the longitudinal wave.

Fig. 1. Map of Japan, showing the Isoseismal Lines and the Position of the Origin of the Earthquake of Jan. 21, 1906.

(I) Boundary of the area of slight motion.
(II) „ „ „ „ of strong motion.



Earthquake of Jan. 21, 1906; 10.50 P.M. (Japan Time).

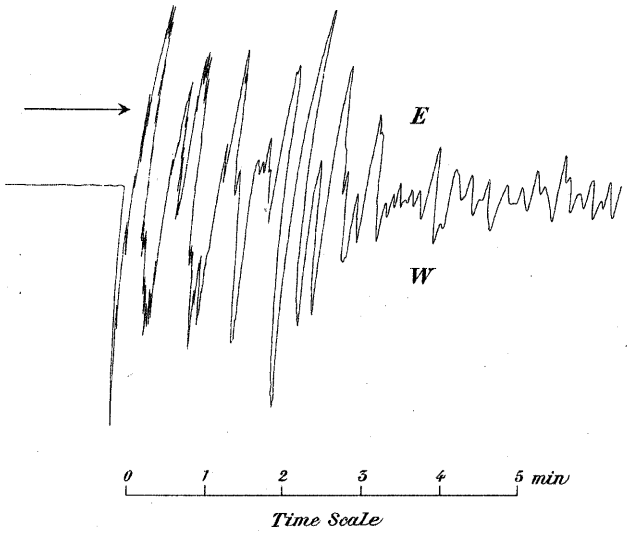


Fig. 4. Kyoto Observation.

EW Component. Multiplication=20.

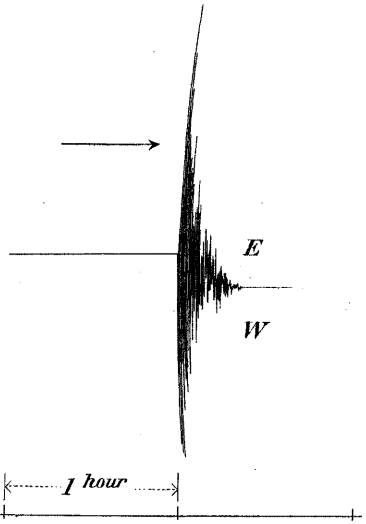


Fig. 3. Osaka Observation.

EW Component.

Multiplication=10.

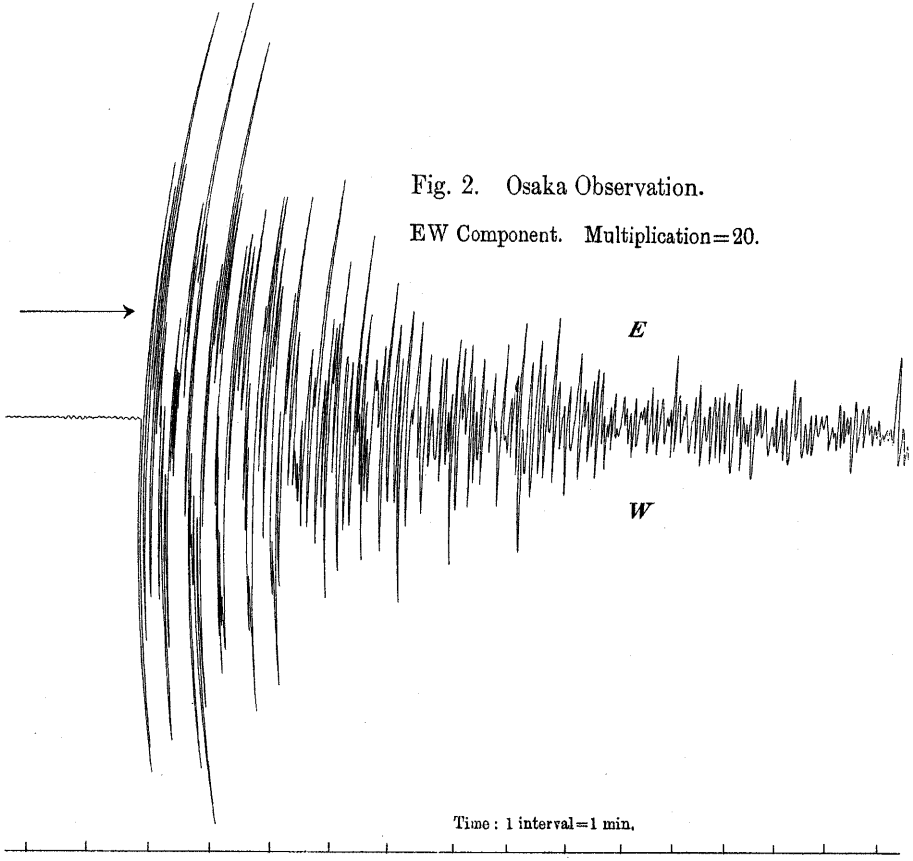


Fig. 2. Osaka Observation.

EW Component. Multiplication=20.

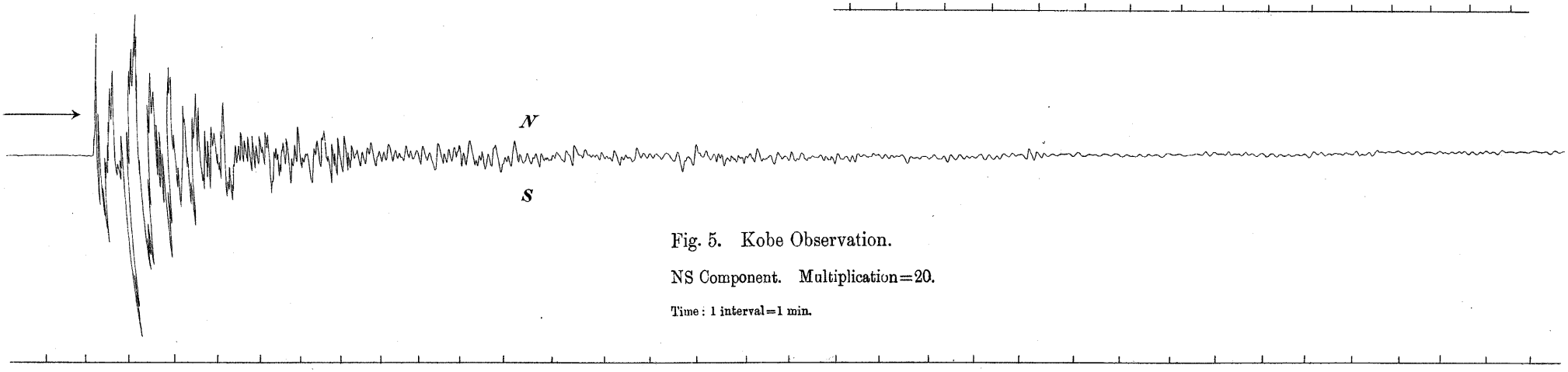


Fig. 5. Kobe Observation.

NS Component. Multiplication=20.

Time : 1 interval=1 min.

a.....Commencement.

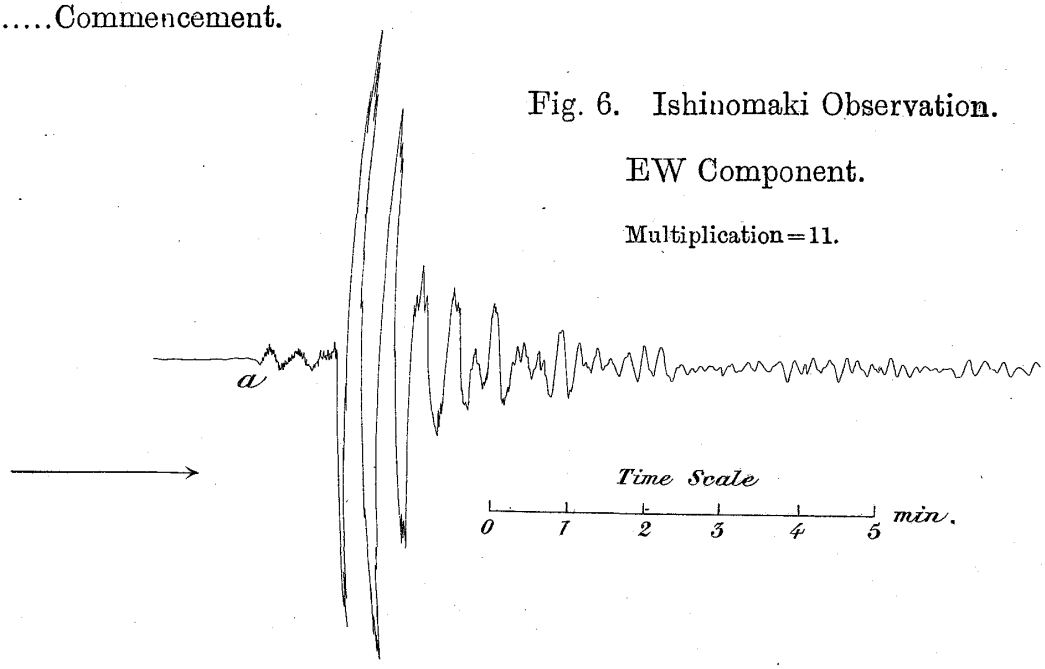


Fig. 6. Ishinomaki Observation.
EW Component.
Multiplication=11.

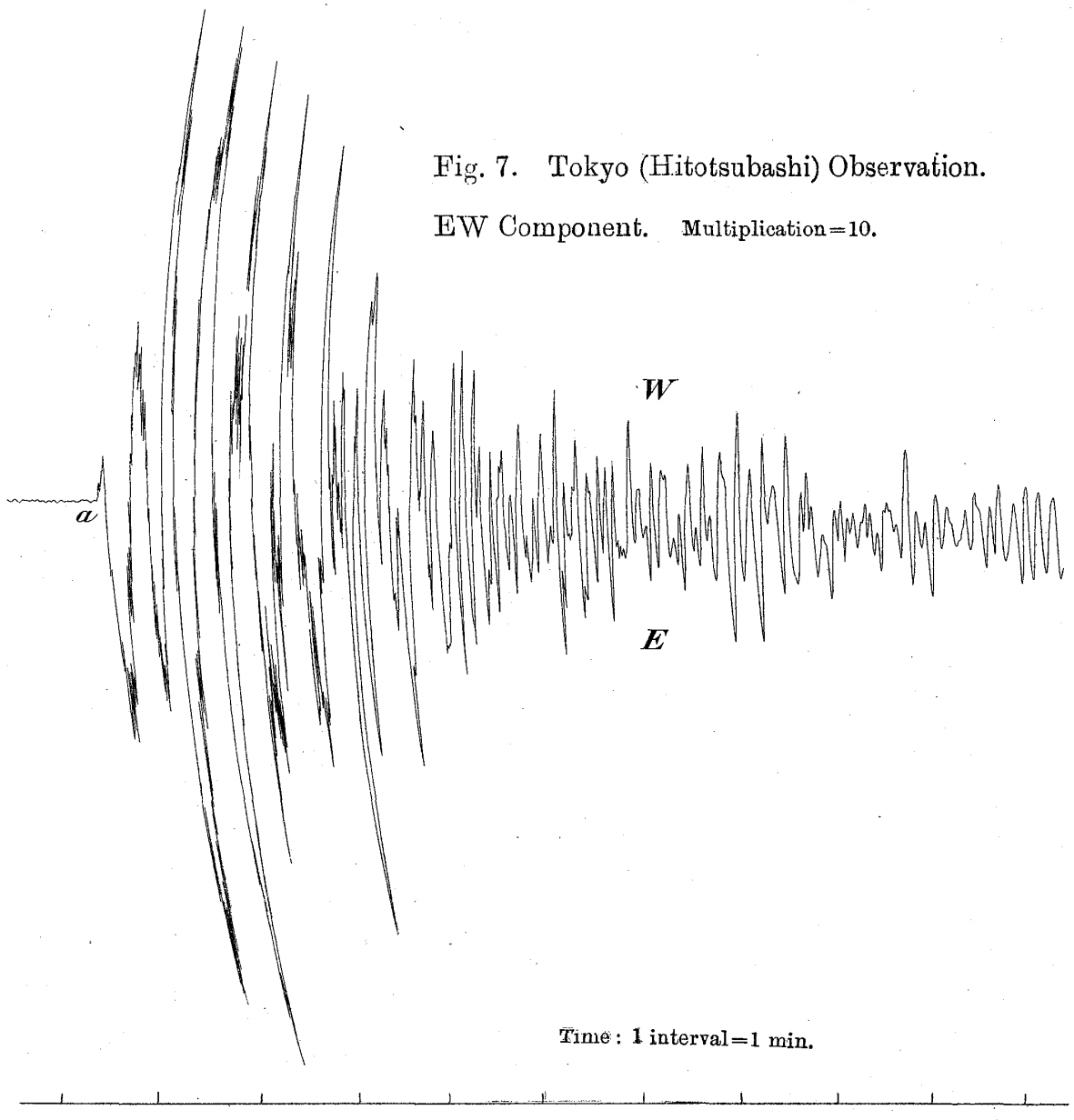


Fig. 7. Tokyo (Hitotsubashi) Observation.
EW Component. Multiplication=10.

Earthquake of Jan. 21, 1906.

Observation in Tokyo (Hongo).

Time : 1 interval=1 min.

a.....Commencement.

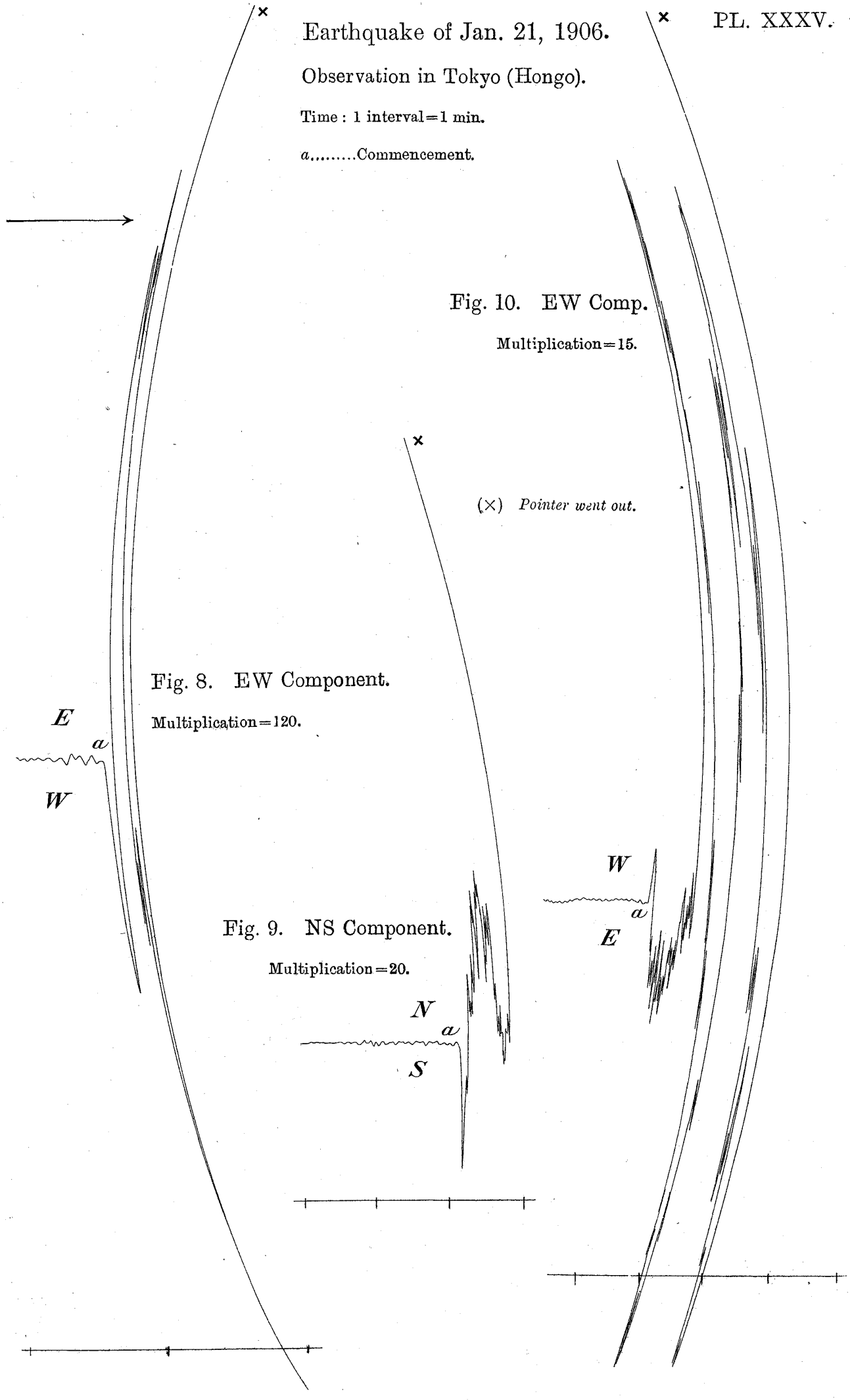


Fig. 8. EW Component.

Multiplication=120.

Fig. 9. NS Component.

Multiplication=20.

Fig. 10. EW Comp.

Multiplication=15.

(×) *Pointer went out.*

Earthquake of Jan. 21, 1906; 10.50 p.m. (Japan Time).

Fig. 11 and Fig. 12. Vertical component, observed in Tokyo.

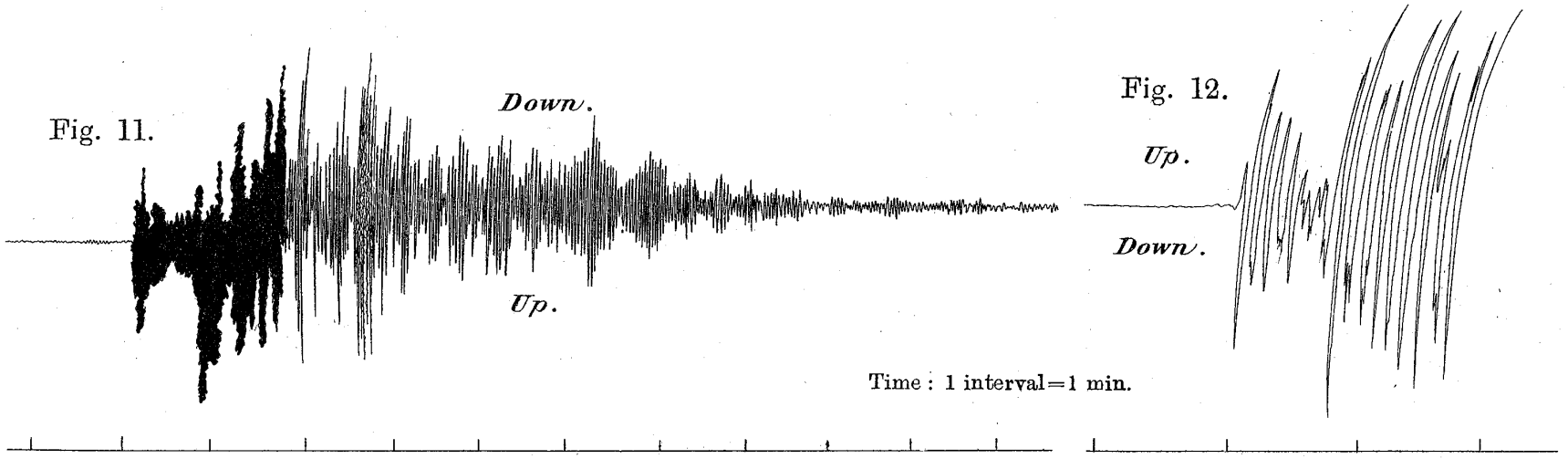
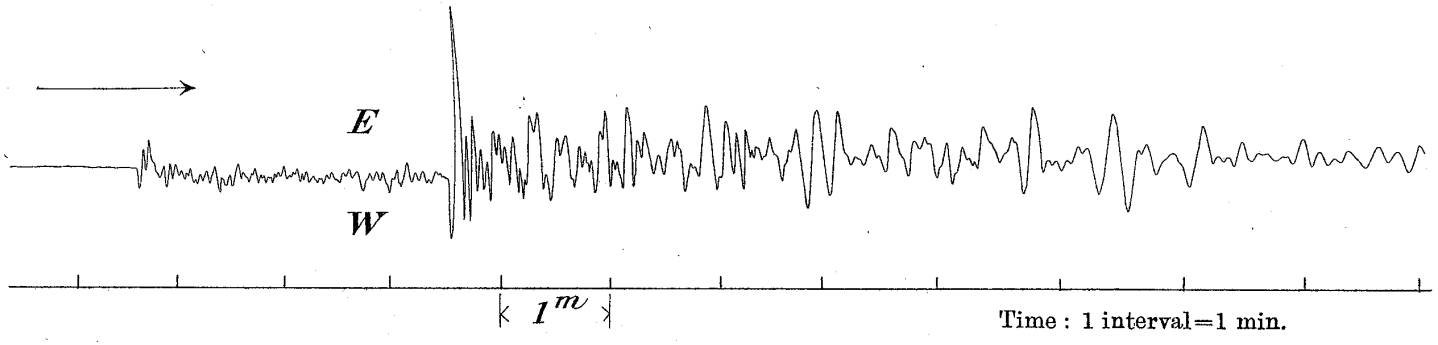


Fig. 13. Observation at Taihoku, Formosa.

EW Component. Multiplication=10.



Earthquake of Jan. 21, 1906.

a.....Commencement.

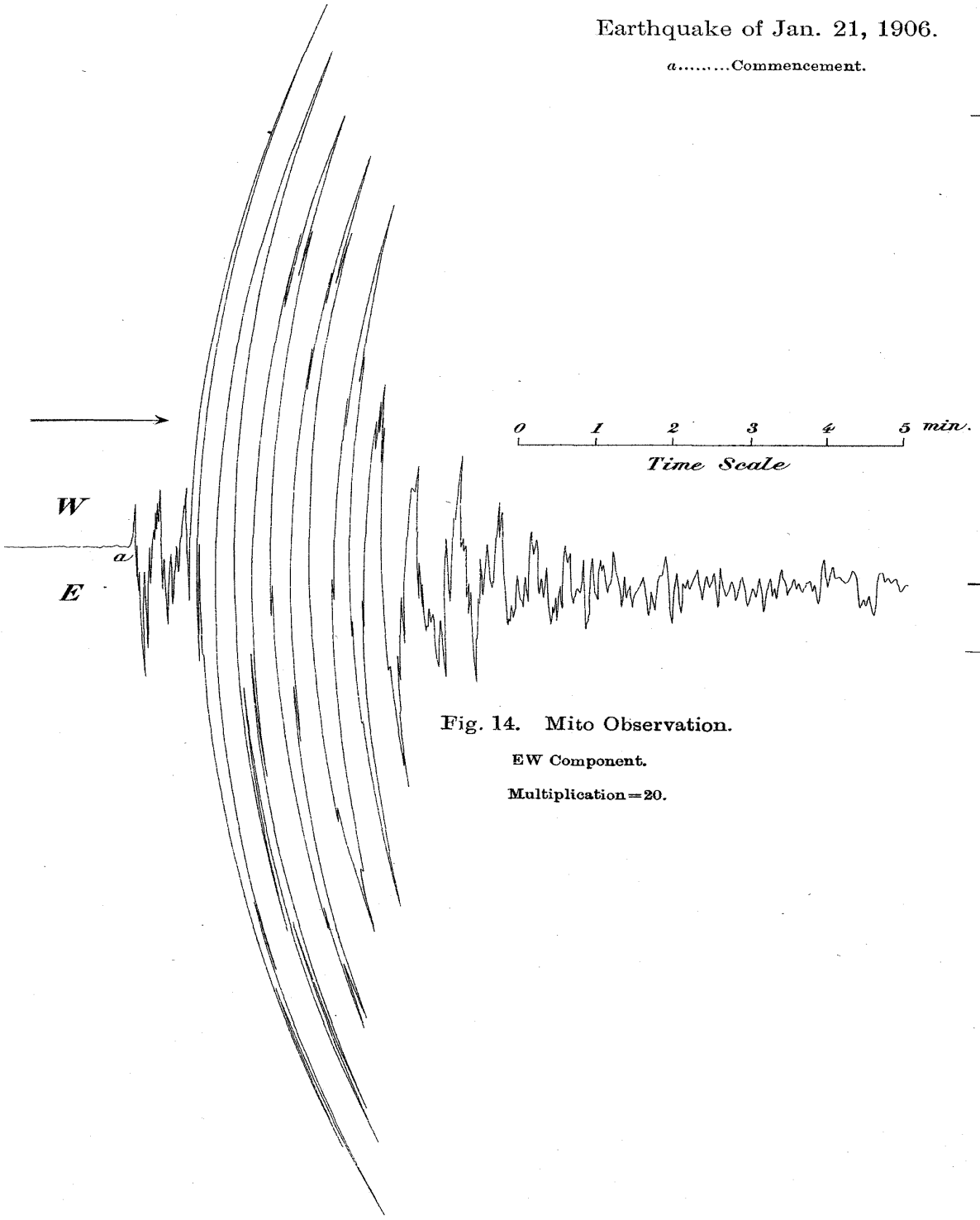


Fig. 14. Mito Observation.

EW Component.

Multiplication=20.

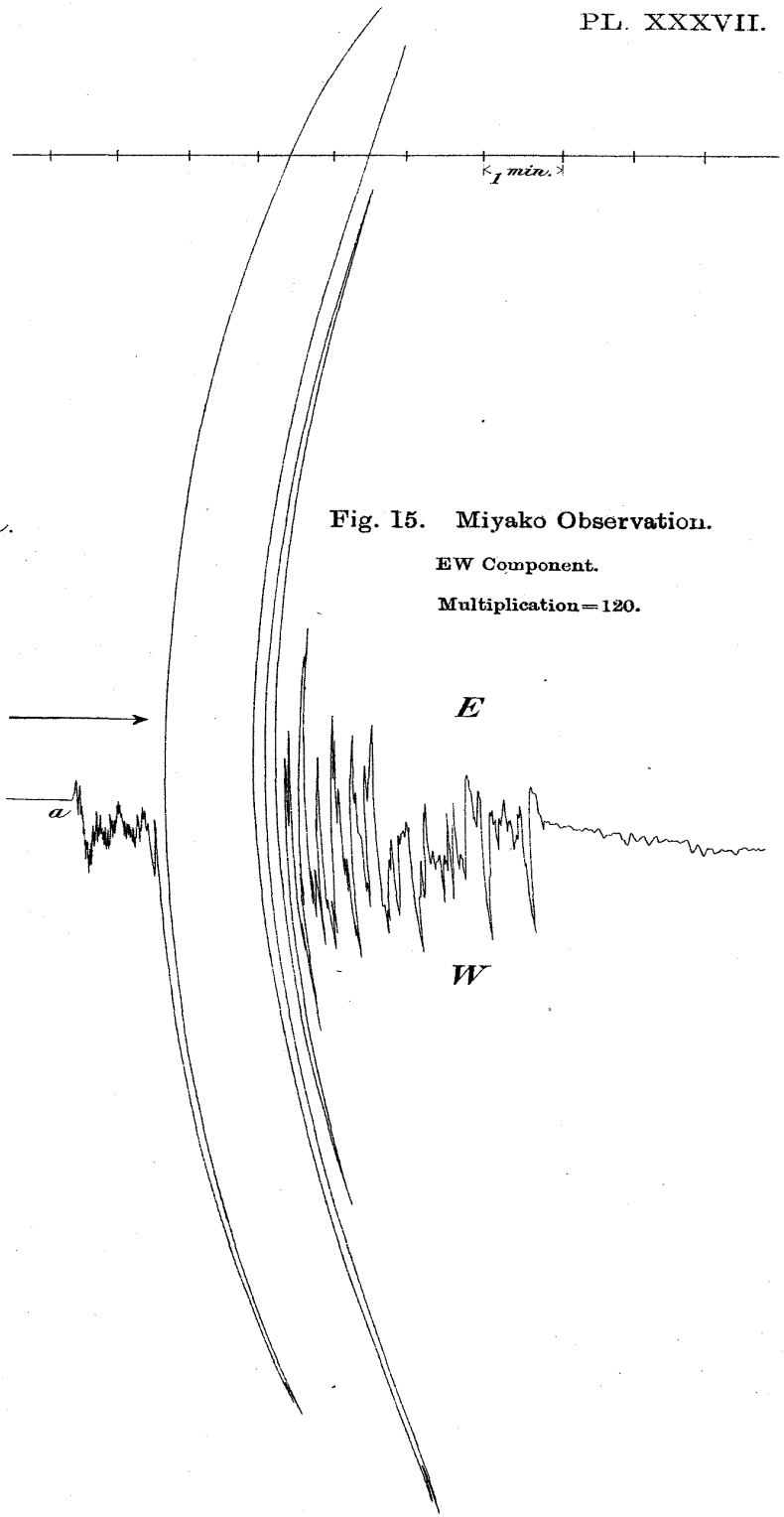


Fig. 15. Miyako Observation.

EW Component.

Multiplication=120.