

Tilting of the Ground during a Storm.

By

F. Omori, Sc. D.,

Member of the Imperial Earthquake Investigation Committee.

1. In the "Publications of the Earthquake Investigation Committee", No. 21, I have described an EW horizontal pendulum or "tiltometer" diagram obtained in Tokyo during a storm, on Oct. 10th and 11th, 1904, which shows the tilting of the ground to an amount of $3\frac{1}{2}''$. Fig. 1, Pl. XL, illustrates a similar case of the tilting of the ground observed on Jan. 10 and 11, 1906, in Tokyo, with the EW component horizontal pendulum, whose recording cylinder makes one revolution in 24 hours. The instrument, which is set up in the brick "Earthquake-proof House" in the University Compound (Hongō), is of the following specifications:—

Length of the strut, or the horizontal distance between the pendulum axis and the centre of the heavy bob= $L=75^{cm}$.

Period of the pendulum when suspended vertically= $T_0=1.74$ sec.

Period of the horiz. pendulum as actually set up= $T=33$ sec.

Multiplication ratio of the pointer= $n=20$.

1mm displacement of the writing index=

$$r = L \times n \times \sin 1'' \times \frac{T^2}{T_0^2} = 0."0385$$

2. *The Weather at Tokyo on Jan. 10 and 11, 1906.** The following table gives the hourly values at Tokyo on Jan. 10th and

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

11th, 1906, of the atmospheric pressure, wind velocity, and the amount of precipitation.

Barometric Pressure,* Wind Velocity, and Precipitation.

Tokyo, Jan. 10 and 11, 1903.

Hour.	Jan. 10th.			Jan. 11th.		
	Barometric Pressure.	Wind Velocity.	Precipitation.	Barometric Pressure.	Wind Velocity.	Precipitation.
	mm. 700+	m/sec.	mm.	mm. 700+	m/sec.	mm.
1 A.M.	69.6	2.8	—	53.1	3.3	1.7
2	69.4	2.2	—	51.1	2.8	1.1
3	69.3	3.3	—	49.3	2.2	3.9
4	68.6	3.3	—	46.5	3.3	4.3
5	68.3	2.4	—	44.6	3.5	8.4
6	68.1	3.7	—	42.7	5.0	22.0
7	67.9	3.7	—	42.3	9.0	6.7
8	67.8	3.7	—	42.6	7.9	0.3
9	67.4	2.8	0.0	42.9	3.3	—
10	67.2	2.2	0.0	43.5	2.6	0.0
11	66.0	0.8	—	43.9	2.8	—
Noon.	64.3	0.8	—	43.8	1.6	—
1 P.M.	63.3	0.8	—	43.4	5.6	—
2	62.6	1.1	—	44.6	7.4	—
3	62.2	1.1	—	45.1	11.0	—
4	61.6	1.6	—	46.3	8.5	—
5	60.9	0.9	—	46.7	8.8	—
6	60.3	1.1	0.0	47.6	10.3	—
7	59.8	1.6	0.0	48.3	9.0	—
8	59.0	2.4	—	48.4	10.8	—
9	57.7	1.8	0.0	49.2	9.4	—
10	57.1	1.8	0.6	49.6	6.3	—
11	55.8	2.4	0.2	49.2	5.6	—
Midnight.	54.2	2.4	0.2	49.2	3.3	—

(* Reduced only to the freezing point. Reduction to standard gravity = -0.63mm , that to mean sea level = $+2.01\text{mm}$.)

As will be seen from the above table, the barometric pressure was 769.6 mm at 1 a.m., on the 10th, thence gradually decreasing to 744.6 mm at 5 a.m., on the 11th. The pressure, which reached the minimum of 742.3 mm at 7 a.m. on the latter day, remained low and less than 744 mm for the next 6 hours. The wind velocity reached a maximum value of 9.0 m/sec. nearly at the moment of the lowest barometric pressure, although greater values of 10.3 to 11 m/sec. were reached at between 3 and 8 p.m. of the 11th. The maximum hourly amount of the precipitation was 22 mm and occurred between 5 and 6 a.m., on the 11th.

The cyclone, which caused the storm in question, first appeared in the morning of the 10th off the south-eastern coast of China and already approached the west coast of Kyushu on the afternoon of the same day, thence progressing in an EEN direction along the Inland Sea. The centre of depression passed, at 7 a.m. on the 11th, between Tokyo and Yokohama, thence moving over the Pacific in a NNE direction, and approaching the north-eastern part of Hokkaido on the afternoon of the same day. The lowest barometric pressure of 724.6 mm was registered at 10 and 11 p.m., on the 11th, at the meteorological observatory of Shana (Kurile Islands).

3. *Tilting of the Ground and Pulsatory Oscillations.* The "pulsatory oscillations" began to appear gradually at 4 p.m., on the 10th, accompanied by a slight tilting of the ground towards E. At 4^h 56^m a.m. on the 11th, (marked *a* in Fig. 1), the rate of the eastward inclination began to become quicker; the maximum displacement of the pointer of the *tiltometer* in the same direction being reached at 5^h 56^m a.m., on the same morning. This moment is marked *b* in the figure, the actual trace on the diagram amounting to 21 mm, which is equivalent to 0".81. At the same time the

pulsatory oscillations became very active, and reached a maximum range of 0.2 mm. Then there began the tilting of the ground towards W, and the maximum displacement of the pointer (marked *c* in the figure) in that direction occurring at 8^h 31^m a.m. on the 11th. The total or double amplitude of the tilting oscillation amounted to 74.6 mm or 2."87.

After 8^h 31^m the tilting began to turn towards E again, the pulsatory oscillations becoming at the same time still more active.

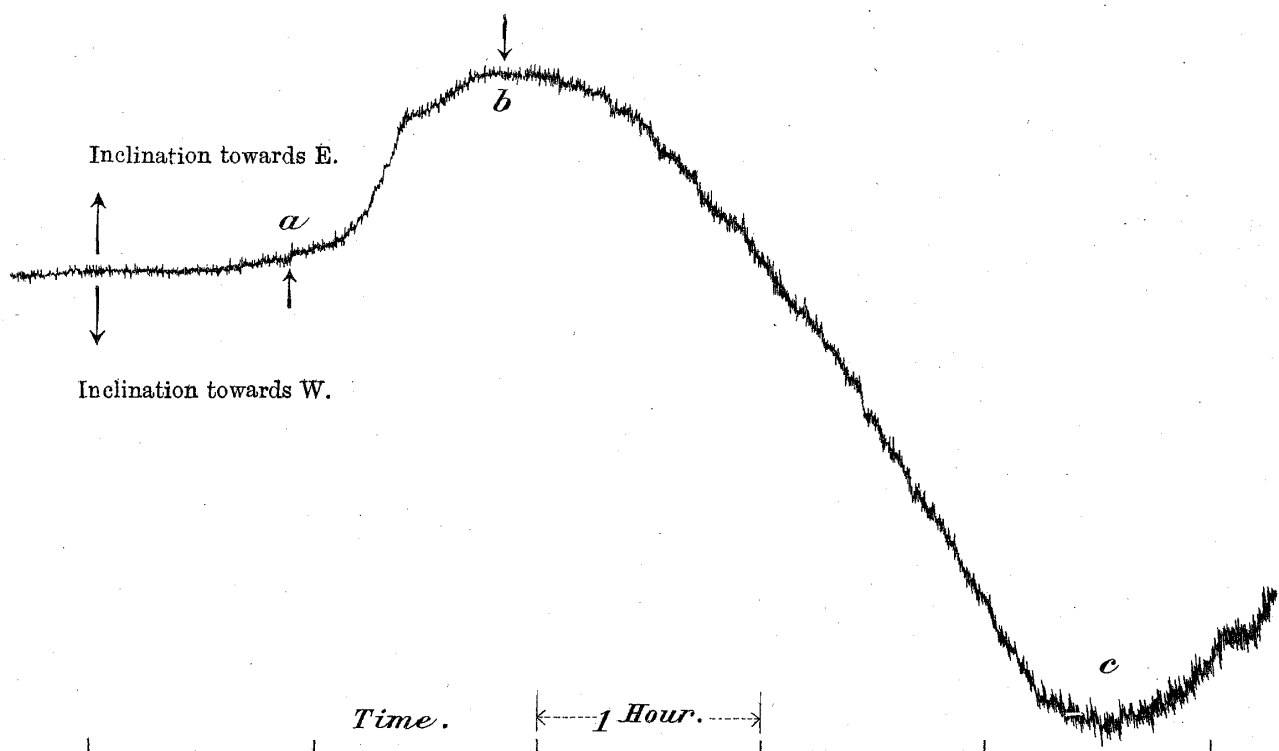
The pointer reached its normal position at about 3^h 15^m p.m., on the 11th; the pulsatory oscillations continuing active (maximum range=0.25 mm) till that time.

Fig. 2 and Fig. 3 give the records furnished by a horizontal pendulum tromometer of multiplication=120, also set up in the "Earthquake-proof House", for a few minutes interval, respectively at about 2 and 4 a.m., on the 11th. The elements of motion were as follows:—

$$\begin{cases} 2 \text{ a.m. (11th).} & \dots\dots \text{max. range} = 0.17 \text{ mm, period} = 6.2 \text{ sec.} \\ 4 \text{ ,,} & \dots\dots \text{,,} = 0.15 \text{ ,, , ,, } 6.4 \text{ ,, .} \end{cases}$$

4. From §§ 2 and 3, it will be seen that the extreme elongation towards E (*b* in Fig. 1) coincided with the epoch of the greatest rainfall, and that the remarkable westward tilting from *b* to *c* nearly coincided with the time interval during which the atmospheric pressure was lowest, namely, between 6 and 9 a.m. (on the 11th). Now the existence of a barometric depression on Musashi, Shimosa and Hitachi plain, or the district lying to the east and north-east of Tokyo, would cause this part of the earth's surface to rise up, the consequence being that there ought to be a westward inclination (*bc*) at Tokyo and the neighbourhood. A similar explanation is applicable to the eastward inclination (*ab*).

Fig. 1. EW Tiltometer Record. Jan. 11, 1906; Hongō, Tokyo.



Pulsatory Oscillations, Observed at Hongō, Tokyo. Jan. 11, 1906. EW Component.
Multiplication = 120.

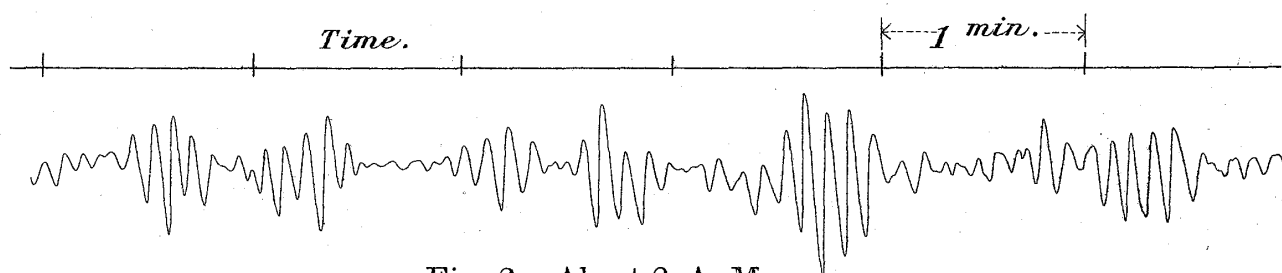


Fig. 2. About 2. A. M.

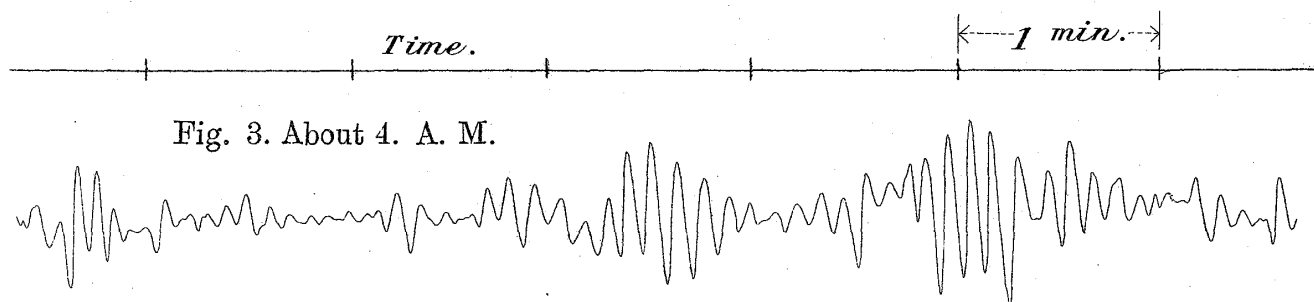


Fig. 3. About 4. A. M.

The demonstration suggested above is rather opposite to that used for the case of the tilting observed in Tokyo on Oct. 10 and 11, 1904. The discrepancy probably lies in the fact that on the latter occasion, the depression moved entirely over the Pacific at a distance of several hundred km. from the coast, while in the present case the track of the cyclone was entirely over the land, from its first entrance in Kyushu to its passage into the ocean at the coast of Hitachi.

Tiltometer observations of the effects of the barometric pressure simultaneously in two rectangular horizontal directions seem to be very interesting in connection with the question of the rigidity of the earth's crust.
