Earthquake Measurement in a Brick Building.

BY

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1.—The great amount of damage done to brick buildings by earthquakes is generally due to the breaking of their walls in consequence of the strong horizontal motion, and therefore it would be of interest to study the shaking during earthquakes of different portions of the walls. As an instance of investigations of this nature, I give in the present paper the result of a seismographical measurement made in the Engineering College of the Tokyo Imperial University, whose object was the comparison of the motion of a wall with that of the ground.*

2.—The wall chosen for the experiment was the external wall of the upper corridor of the western side of the Engineering College, and the motion was recorded by Prof. Ewing's Horizontal Pendulum Seismograph fixed near the top of the wall at the middle of its length. (See figs. 1 and 2.) Another seismograph of the same pattern was set up on the ground between the Engineering College and the Geological Institute, and its record was taken as representing the earthquake motion of the basement of the former, there being no particular topographical irregularity in the grounds, on which these buildings stand. Subsequently the ground-surface obser-

* Similar measurement with duplex pendulum seismographs have been made in 1883–4 by Prof. J. Milne. See his paper: *The movement produced in certain buildings by earthquakes.* Trans. Seis. Soc. Vol. XII.

vations were discontinued, and the records of the instrument in the Seismological Institute were substituted. All the seismographs multiplied the motion five times, the measurement having been restricted only to the horizontal component of the earthquake motion.

3.—The experiment was carried on between 1894 and 1898, during which period ten moderate earthquakes have successfully been recorded. The result is summarized in the following table.

SUMMARY OF RESULT.

Date of Earthquake.	Component.	Intensity.	Period. sec.	Max. Hor. Mot. On the ground. mm.	Max. Hor. Mot. Upstairs. mm.	Ratio. (Upstairs / Ground)
May 10th, 1894 …………	(EW)	Slight.	0. 4	0. 1	0. 2	2.0
June 25th, 1894 …………	(NS)	Weak.	. 9	3. 7	4. 6	1.2
July 15th, 1894 ……….	(EW)	Slight.	……	. 6	. 3	.5
	(NS)		.52	. 6	. 3	.5
Nov. 15th, 1894 …………	(EW)	Slight.	.23	. 2	. 3	1.8
	(NS)			.14	. 1	.7
Nov. 30th, 1894 { Slow undulation	(EW)	Strong.	……	2. 9	3.	1.0
	(NS)		……	2. 9	3. 2	1.1
Nov. 30th, 1894 { Ripples	(EW)		.23	1. 4	2.	1.4
	(NS)		.22	1. 6	3. 2	2.0
April 9th, 1895……………	(EW)	Slight.	.22	.18	.16	.9
July 17th, 1895 …………	(EW)	Slight.	. 5	. 5	. 7	1.4
	(NS)		.77	. 8	. 8	1.0
March 6th, 1896 …………	(EW)	Weak.	.43	2. 2	2. 0	.9
	(NS)		.43	3. 2	4. 3	1.3
Oct. 20th, 1897 …………	(EW)	Slight.	.14	. 3	. 5	1.7
	(NS)		……	. 3	. 9	3.0
March 27th, 1898 ………	(EW)	Slight.	.22	.14	. 8	5.7
	(NS)		.23	.24	. 8	3.3

To the above table the following explanatory notes may be added.

Eqke. No. 2. Intensity *weak.* The motion had a single well-pronounced maximum.

Eqke. No. 4. Intensity *slight.* The motion had no well-pronounced maximum.

Eqke. No. 5. Intensity *weak.* The duration was 80 seconds.

(Engineering College, upstairs.) The *preliminary tremor* consisted of vibrations of an average period of 0.18 sec. in the EW and 0.21 sec. in the NS direction and was followed abruptly by larger movements which were most active for the next 2.2 seconds, and whose average period was 0.23 second in the EW and 0.19 second in the NS direction. The maximum horizontal motion was 2 mm in the EW and 3.2 mm in the NS direction. Measuring at about 22 seconds from the commencement, the average period was found to be 0.22 second in each direction.

(Engineering College, ground surface.) The *principal portion* whose maximum motion was 1.4 mm in the EW and 1.6 mm in the NS direction had an average period of 0.22 second in the EW and 0.19 second in the NS direction. Measuring at about 23 seconds from the commencement, the average period was found to be 0.22 second in each component.

Eqke. No. 7. Intensity *weak.* The duration was 100 seconds.

(Seismological Institute.) The *preliminary tremor* was followed abruptly by the maximum motion. The average period of vibration in the principal portion was in the EW component 0.4 second.

Eqke. No. 8. Intensity *weak.* The duration was 90 seconds.

(Engineering College, upstairs.) The *preliminary tremor* was followed abruptly by a well-defined maximum movement, whose period was 0.36 second, and whose range was 2 mm in the EW and 4.1 mm in the NS direction, the rest of the shock consisting of far smaller vibrations. In the NS direction, the average periods of vibration in the *preliminary tremor*, *principal portion* and *end portion* were respectively 0.3, 0.4 and 0.46 second.

(Seismological Institute.) The maximum motion was 2.2 mm in the EW and 3.2 mm in the NS component, the average period in the *principal portion* being 0.41 second.

Eqke. No. 9. Intensity *slight*. The earthquake consisted of very quick vibrations, the average period being in the EW direction 0.14 second. (Seismological Institute.)

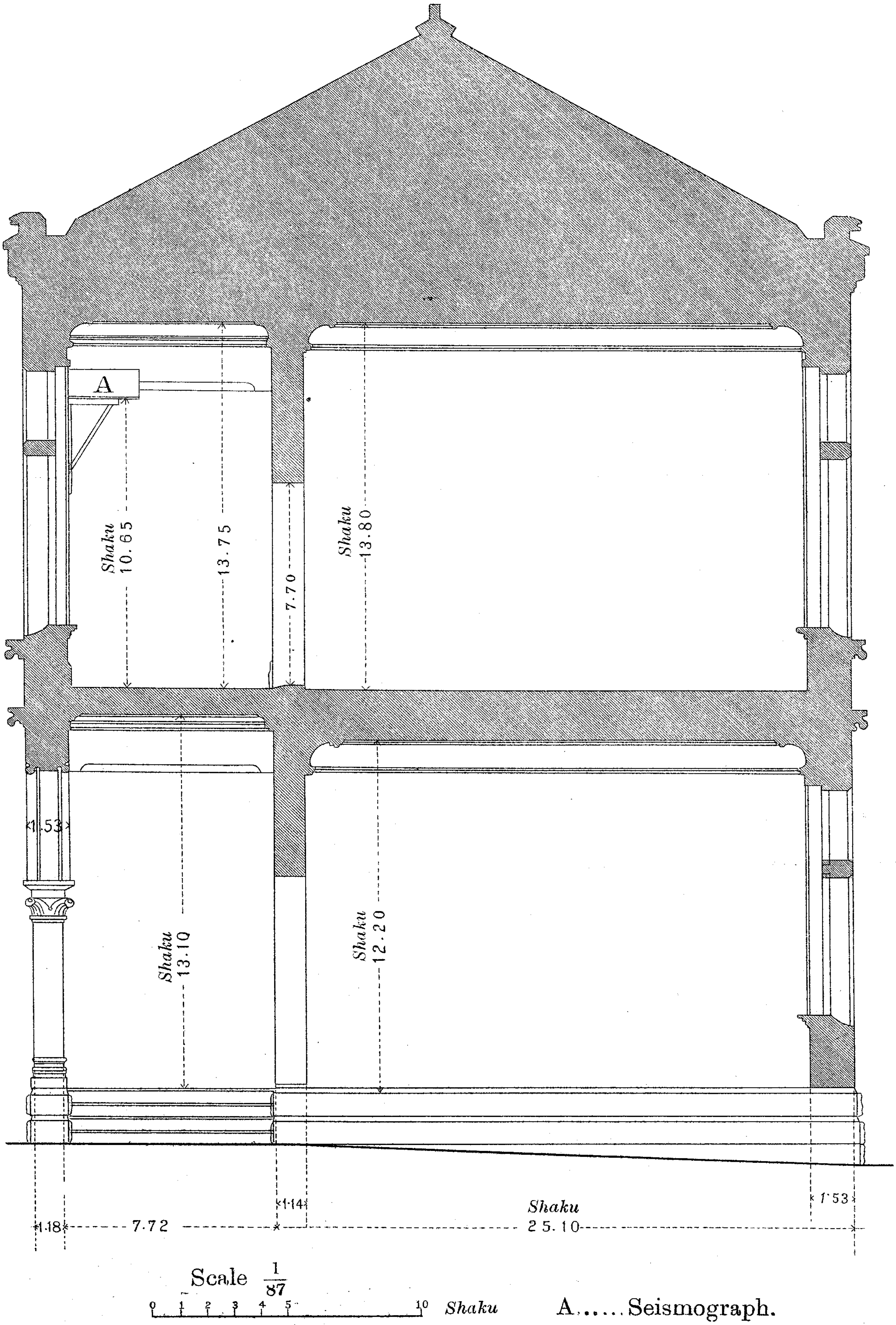
4.—As will be seen from the table, the motion of earthquakes Nos. 2, 3 and 7, which consisted of vibrations of comparatively slow period, that is to say, above 0.5 second, was practically the same in the upper storey of the Engineering College as on the ground surface, the mean ratio of the ranges of motion at these two stations being 1. On the other hand in the remaining seven earthquakes which consisted of quick-period vibrations, the motion of the top of the wall was greater in the average ratio of 2:1 than that of the ground surface. As besides, the period of vibration was the same in both cases, it seems that in shocks of violent nature the wall, on which the roof rested, behaved like an inverted pendulum subjected to a forced vibration, its motion synchronizing with the earthquake motion. Figs. 3a, 3b, 4a and 4b, give, as typical illustrations of this kind, the diagrams of earthquakes Nos. 5 and 8.

Practically, in cases of destructive earthquakes, the damage of two-storied brick buildings is in general limited to the upper storey.

Thus it is not seldom that the walls of the lower storey remain uninjured or very slightly cracked, even though the damage to the upper storey be so severe that its walls are knocked down and its roof fallen in. This is evidently due to the magnification of motion in the upper storey walls. Typical illustrations are given in figs. 5 and 6 which represent the condition after the great earthquake of Oct. 28th 1891, of the Aichi Cotton Mill and the Post and Telegraph Office, both at Nagoya.

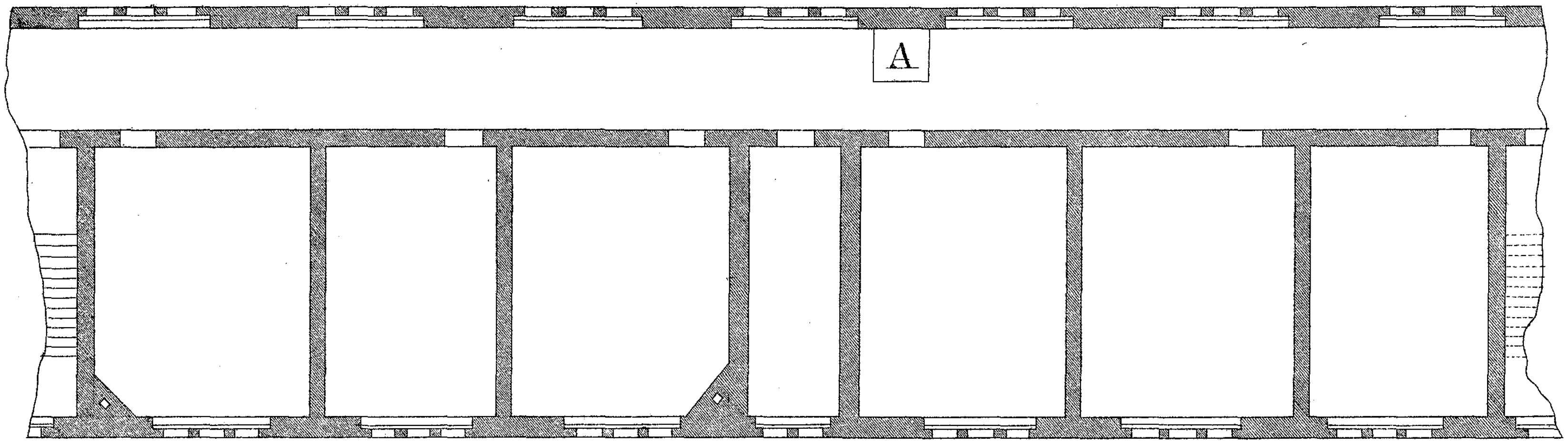
Fig. 1. WEST SIDE OF THE ENGINEERING COLLEGE.

(Section.)

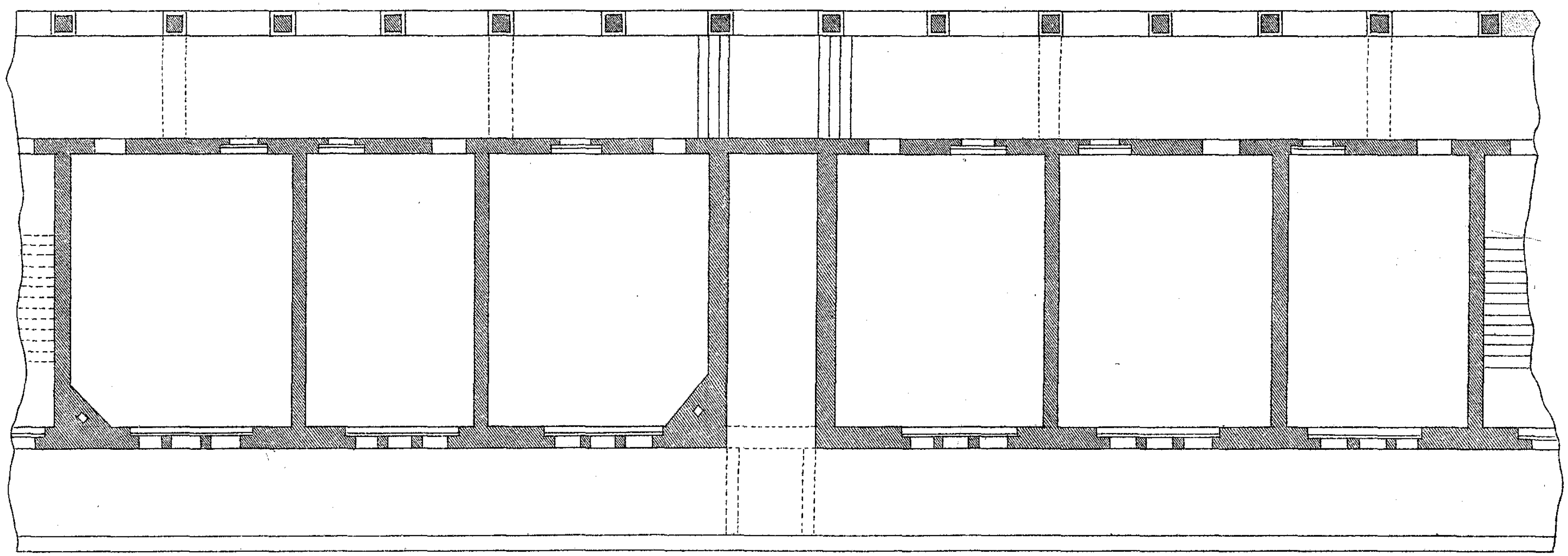


A......Seismograph.

Fig. 2. WEST SIDE OF THE ENGINEERING COLLEGE.



(Upper Floor.)



(Ground Floor.)

Scale $\frac{1}{210}$.

A............Seismograph.

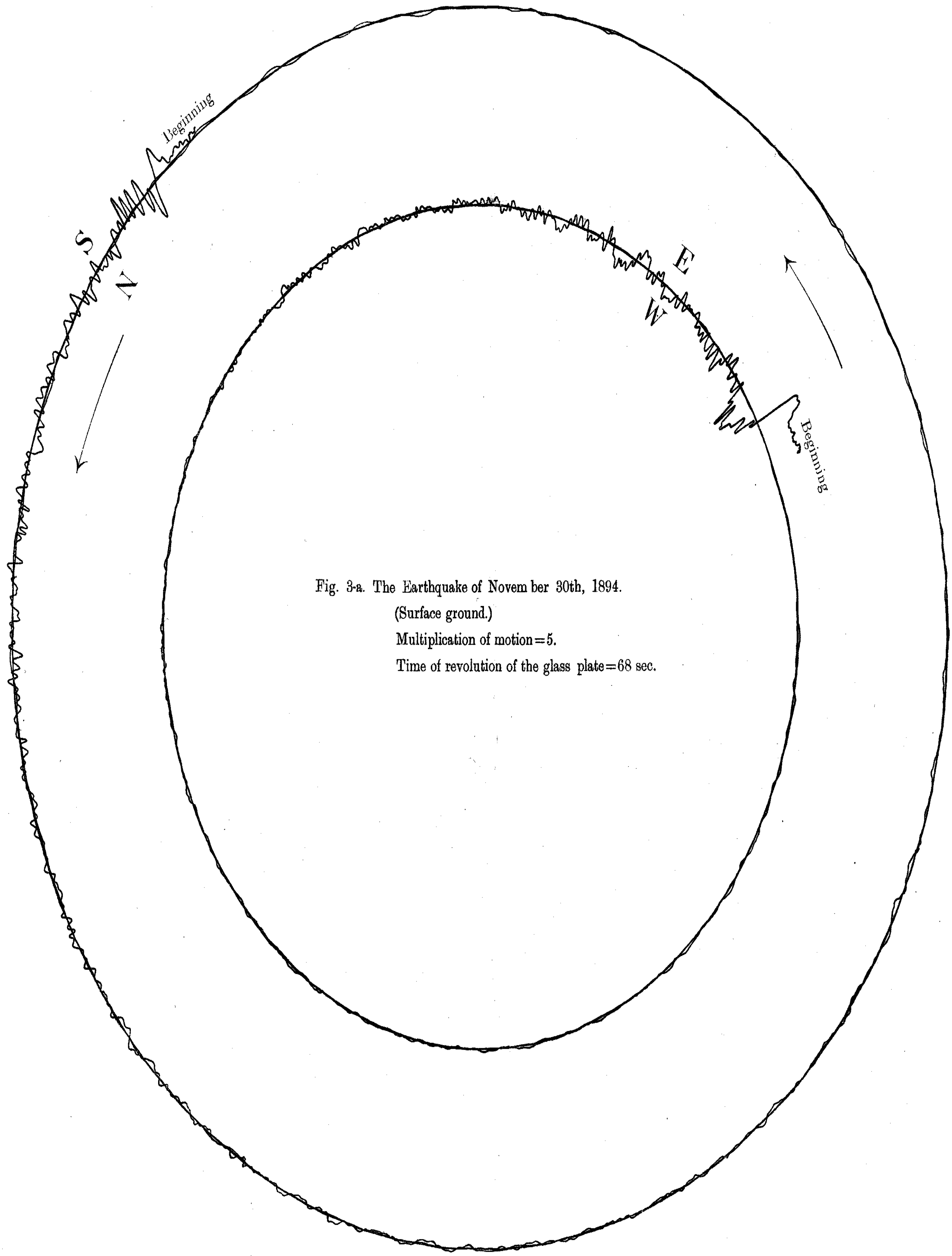


Fig. 3-a. The Earthquake of November 30th, 1894.
(Surface ground.)
Multiplication of motion = 5.
Time of revolution of the glass plate = 68 sec.

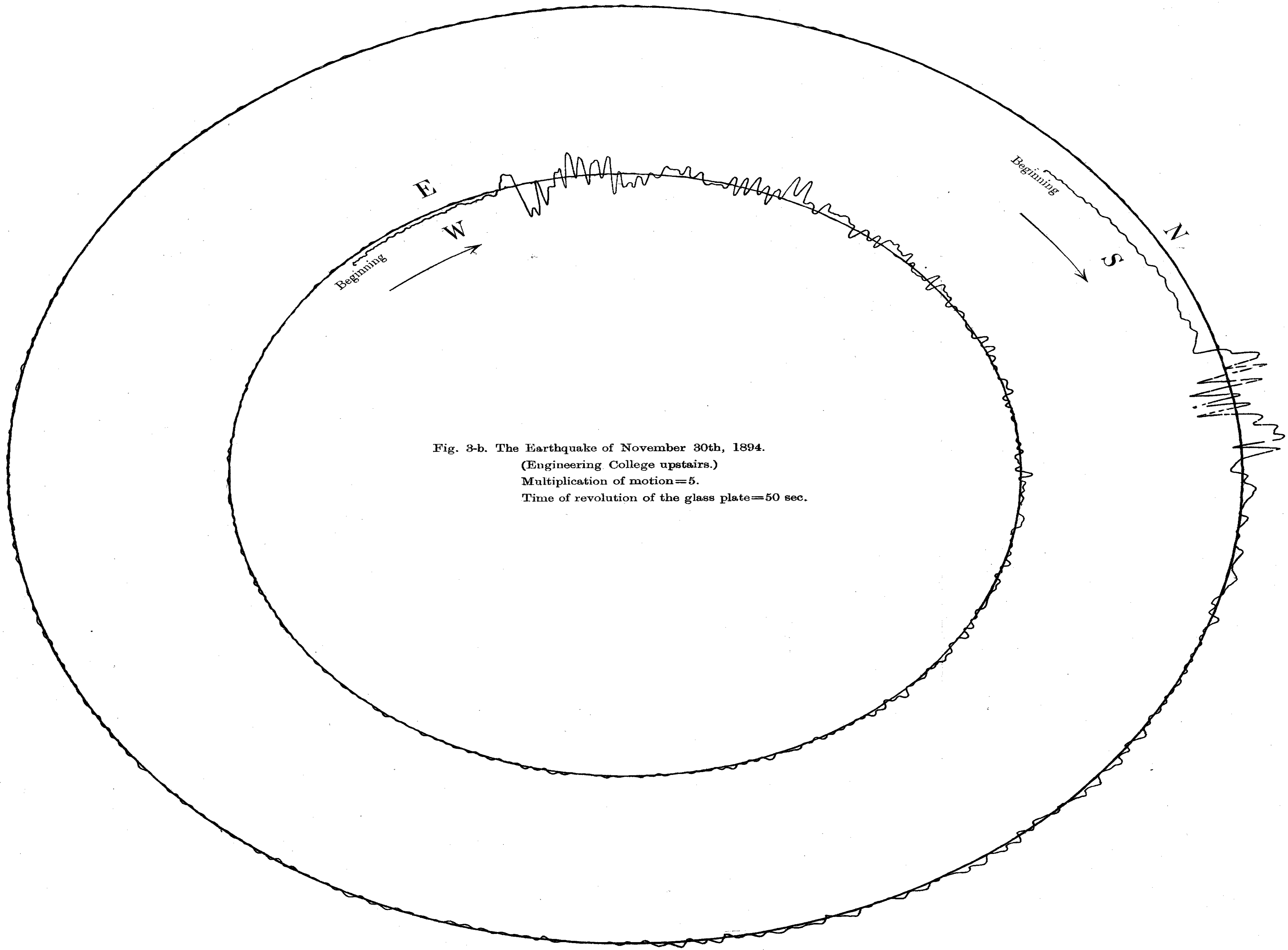


Fig. 3-b. The Earthquake of November 30th, 1894.
(Engineering College upstairs.)
Multiplication of motion=5.
Time of revolution of the glass plate=50 sec.

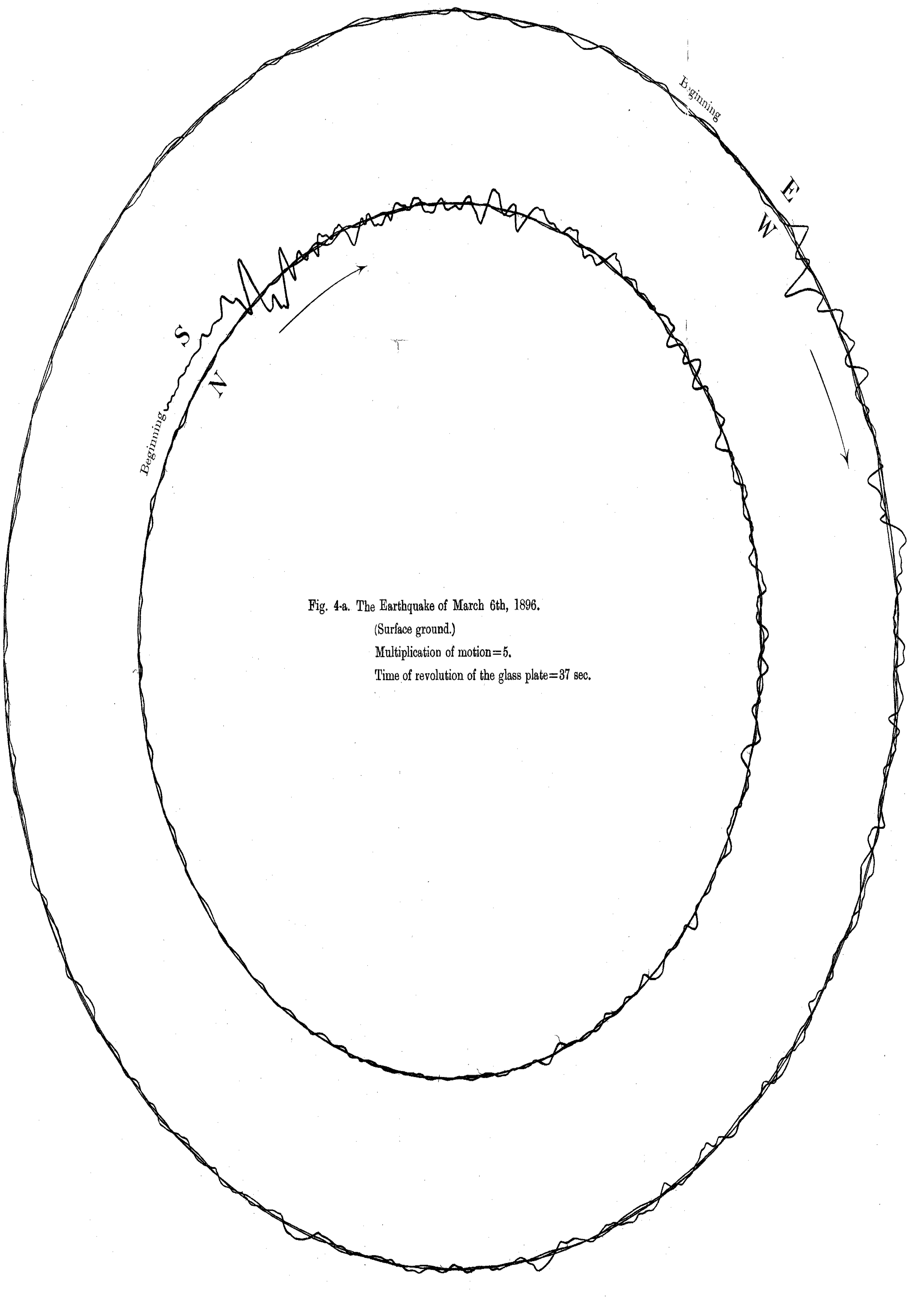


Fig. 4-a. The Earthquake of March 6th, 1896.
(Surface ground.)
Multiplication of motion=5.
Time of revolution of the glass plate=37 sec.

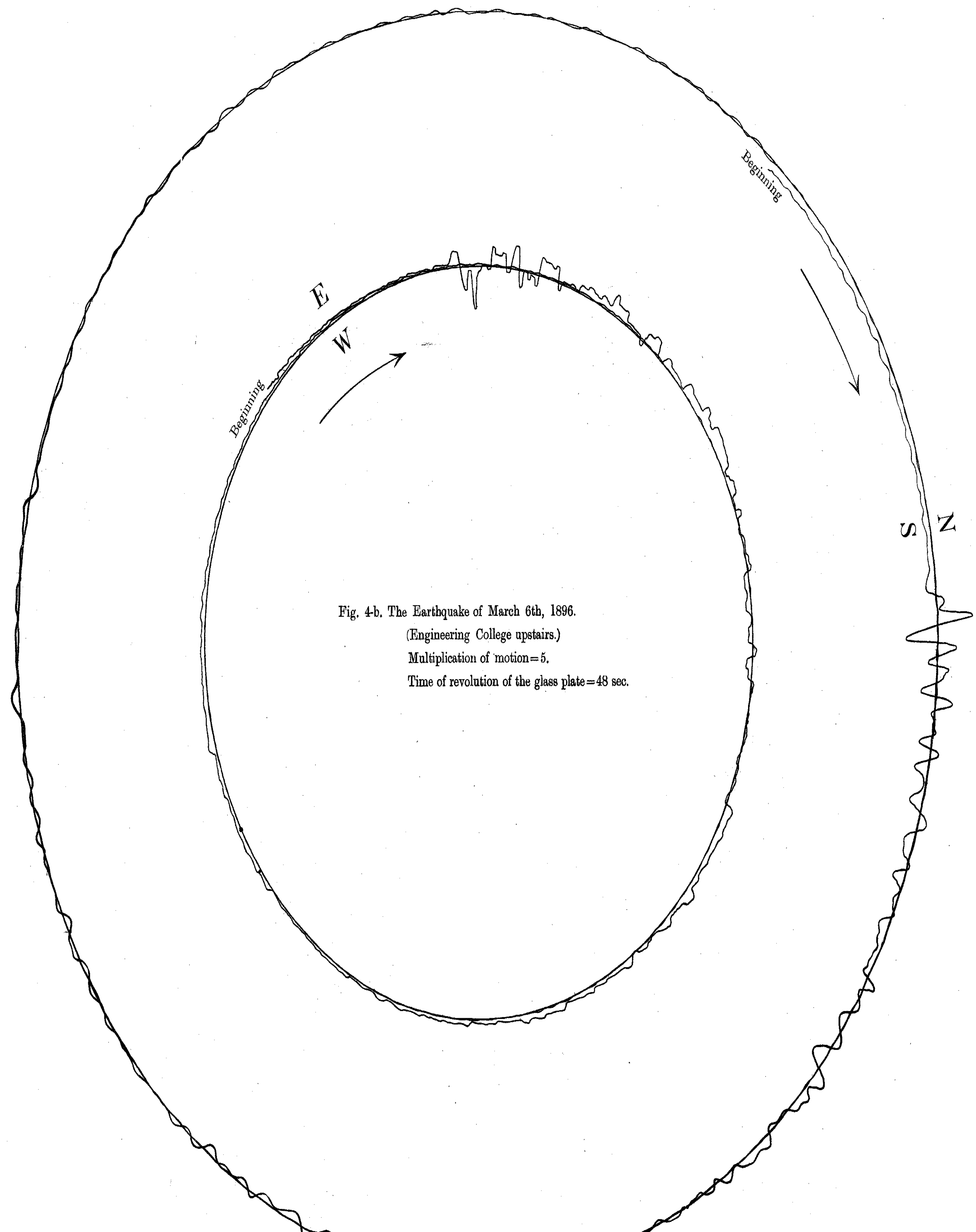


Fig. 4-b. The Earthquake of March 6th, 1896.
(Engineering College upstairs.)
Multiplication of motion = 5.
Time of revolution of the glass plate = 48 sec.

Fig. 5. COTTON SPINNING MILL, NAGOYA. Oct. 28, 1891.

Fig. 6. POST AND TELEGRAPH OFFICE, NAGOYA. Oct. 28, 1891.