

# On Micro-tremors.

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With Pls. I-III.

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**Introduction.** The non-seismic vibrations of the ground called “pulsatory oscillations” are small slow movements with periods generally of about 4 or about 8 sec., possibly all over the world. These oscillations, which are most markedly shown at Tokyo, Osaka, and other places situated on an extensive plane of new formation, and also probably at mid-ocean islands\*, have sometimes a double amplitude of 0.5 mm or more. What I propose here to term *micro-tremors* are those insensible movements of the ground, whose period is usually less than 1 sec., and whose amplitude is much smaller than that of the pulsatory oscillations. In short, the micro-tremors are, whatever their origin may be, extremely minute vibrations of a nature similar to that of the movements composing the macro-seismic, or sensible, part of the earthquake motion proceeding from a near centre of disturbance.

The diagrams furnished by Omori horizontal tremor recorders and tromometers‡, of 90 to 300 times magnifications, set up in

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\* As shown by the Omori Hor. Pend. Tromometer observation at the meteorological observatory of Hachijo-jima, an island belonging to the Fuji volcanic chain.

‡ These instruments are improved forms of those described in the *Publications*, No. 18, and the *Bulletin*, Vol. I, No. 4.

Osaka and Tokyo indicate the micro-tremors often quite distinctly. For the sake of clearness, however, some photographic enlargements of the original records are reproduced in Pls. I to III. I give next the results of some preliminary investigations on micro-tremors.

**Observation at Hitotsubashi (Tokyo).** The observation at Hitotsubashi was made with a horizontal pendulum tromometer of 100 times magnification. The maximum double amplitude in the EW component was about 0.0015 mm, the average periods, each deduced from 100 consecutive vibrations, being as follows:—

Date (1907).		Average Period (EW Component).	
July	5-6	0.80 sec.	} ..... <i>Mean</i> , <b>0.83</b> sec.
"	"	0.91	
"	"	1.01	
Oct.	29-30	0.84	
"	30-31	0.83	
"	"	0.82	
Nov.	22-23	0.77	
"	"	0.88	
"	28-29	0.60	
"	"	0.82	

The mean period of micro-tremors at Hitotsubashi is thus seen to be 0.83 sec. To compare these tremors with the quick vibrations actually occurring in an earthquake, I give in Pl. I a part of the tromometer record for July 5 and 6, 1907, which was photographically enlarged 8 times and thus magnifies 800 times the movements of the ground, with a time scale of 197.4 mm for

1 minute. The seismic disturbance shown in the diagram consists of the preliminary tremor and the earlier part of the principal portion of the earthquake of July 6, 1907, which originated under the sea about 900 km to the NE of Tokyo and was felt strongly at the coast of Nemuro and Kushiro (Hokkaido). In Tokyo, the shock was slight, and the total duration about 2 hours, the time of occurrence being 0h 48m 07s A.M. According to Pl. I, the quick vibrations in the preliminary tremor, which lasted 90.0 sec. (the commencement is marked *a*), were as follows\* :—

Average  $T=0.77$  sec., Max.  $2a=0.074$  mm.

The active vibrations at the commencement (marked *b*), of the principal portion was as follows :—

Average  $T=0.88$  sec., Max.  $2a=0.36$  mm.

Thus the mean period of the macro-seismic movements was in this case about 0.83 sec., which happens to be identical with the average period of the micro-tremors (at Hitotsubashi) as given in the foregoing table. Especially, the larger and slower ones of these tremors, as those marked *e* and *f* (Pl. I), will be seen to be similar in nature to the prominent vibrations occurring in the principal portion (*b*) of the earthquake. Finally, for the sake of reference, I may state that, according to the result of the macro-seismic measurement in Tokyo†, the average period at Hitotsubashi was found to be 0.77 sec., this characterizing the ordinary earthquake vibrations. The period of strong shocks at the same place is a little longer and equal to 0.9 to 1.0 sec.

**Observation at Hongo (Tokyo).** The micro-tremors at Hongo are probably somewhat smaller than those at Hitotsubashi,

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\*  $T$  and  $2a$  denoting as usual the complete period and the double amplitude, respectively.

† The "Publications," No. 11, p.p. 51 and 52.

the max. 2a in the EW component being about 0.0011 mm. Pl. II is a part of the diagram for Jan. 23, 1908, furnished by an EW component horizontal tremor-recorder with an original pointer multiplication of 300 times, enlarged photographically 8 times, the resultant magnification being thus equal to 2,400, with a time scale of 835 mm for one minute. The average periods of the micro-tremors each deduced from 200 consecutive vibrations, were as follows :—

Date (1908).	Average Period (EW Component).
Jan. 20-21	0.28 sec.
„ 22-23	0.28
„ 24-25	0.28
„ „	0.32
<i>Mean</i> .....	<b>0.29</b> sec.

The mean value of the period of the micro-tremors was in these cases 0.29 sec., which is not much different from those of the quick vibrations and ripples occurring at Hongo in actual earthquakes. Thus, according to the macro-seismic measurement at Hongo\*, we have the following results :—

{	Average period of max. quick horizontal vibrations	=0.26 sec.
	„ superposed horizontal ripples	=0.20 „
	„ max. quick vertical vibrations	=0.25 „

**Observation at Osaka.** The horizontal tremor-recorder with a multiplication of 90 times, at the Osaka Meteorological Observatory (Director, Mr. N. Shimono,) indicates micro-tremors much more distinctly than in Tokyo, the max. 2a's in the EW

\* See the *Publications*, No. 11, p.p. 53-55.

and NS components being each about 0.008 mm. Pl. III is a part of the record for Dec. 28, 1907, enlarged photographically 7.8 times, so that the resultant magnification is about 700 times. The average period of micro-tremors was as follows:—

Date (1907).	Average Period*.	
	EW Component.	NS Component.
Nov. 18-19	0.81 sec. (100)	0.90 sec. (100)
„ „	0.88 (100)	0.95 (100)
„ 21-22	0.77 (100)	0.88 (100)
„ „	0.80 (100)	0.84 (100)
Dec. 20-21	0.74 (200)	0.87 (200)
„ 21-22	0.68 (200)	0.89 (200)
„ 22-23	0.74 (200)	0.84 (200)
<i>Mean</i> .....	<b>0.76</b>	<b>0.88</b>

The average period of the micro-tremors obtained by taking the mean from the two horizontal components is 0.82 sec. In this connection it is interesting to note that the ordinary seismograph observation at the same observatory of the vibrations caused by a powder explosion at a distance of 5 km in one of the suburbs of Osaka indicated also similar periods, as follows†:—

$$\left\{ \begin{array}{l} \text{Vertical motion....Aver. } T=0.75 \text{ sec. (Max. } 2a=0.40 \text{ mm);} \\ \text{EW „ .... „ } =0.83 \text{ „ ( „ } =0.48 \text{ „);} \\ \text{NS „ .... „ } =0.82 \text{ „ ( „ } =0.24 \text{ „);} \end{array} \right.$$

the mean value of the period of the horizontal motion being thus

\* The numbers of consecutive vibrations, from which the average period was deduced is in each case indicated by the figures 100 or 200, enclosed within brackets.

† An account of the vibrations caused by the powder explosion at Fuku-mura, near Osaka, is given by the present author in the Reports (Japanese) of the Imp. Earthquake Inv. Comm., No. 57.

0.82 sec. In the cases of the strong Inland Sea earthquake of June 2, 1905, and two of its after-shocks, the period of the maximum horizontal motion at Osaka was about 1.0 sec.

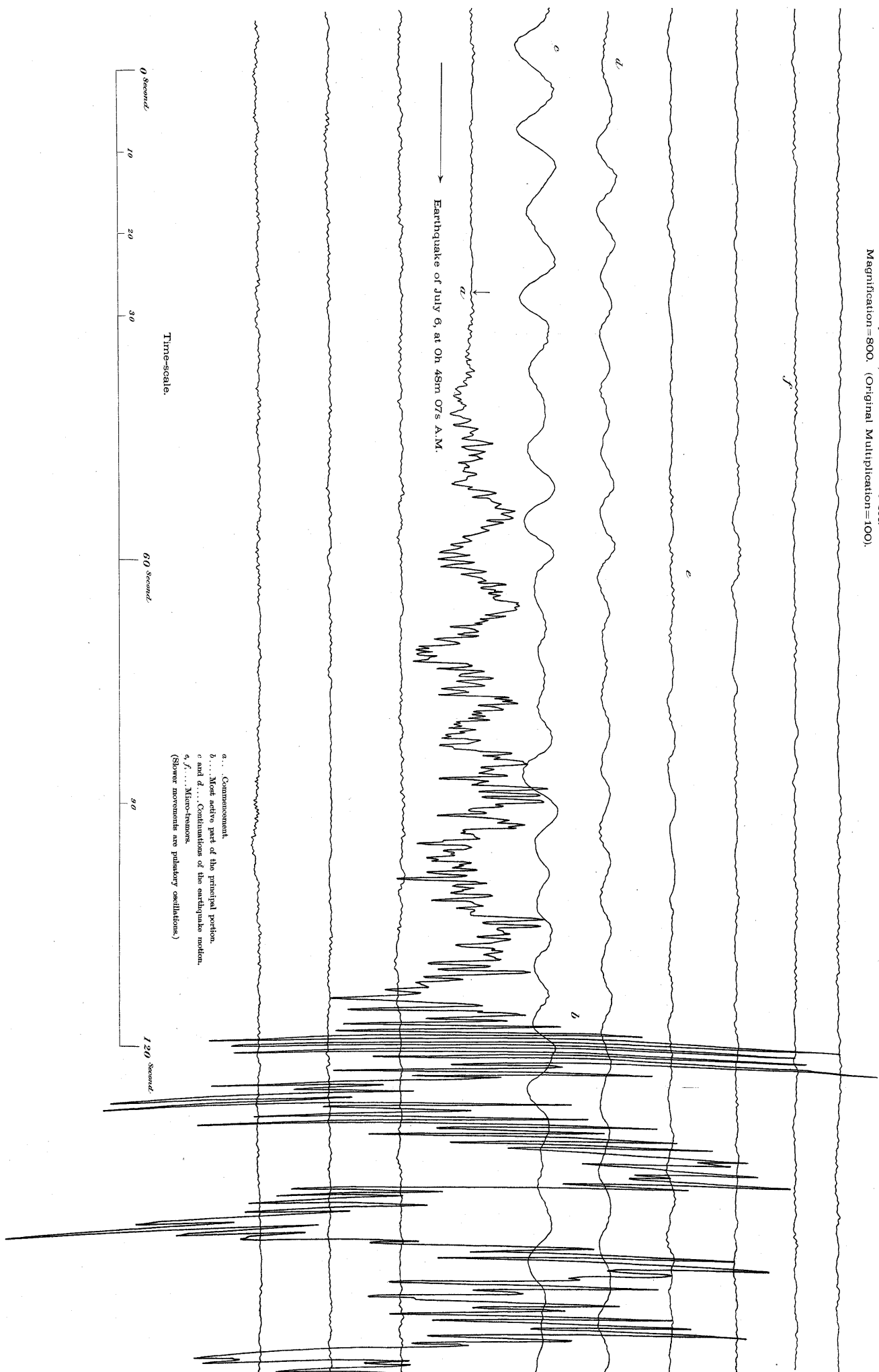
**Conclusion.** The micro-tremors at Tokyo and Osaka seem to occur chiefly during the day time, and may be due to traffic and other artificial causes, and also to the impact of winds against the ground. At any rate, however, their periods seem to be nearly identical with those of the ordinary sensible, or macro-seismic, vibrations at the respective places of observation, just as the period of the pulsatory oscillations are found to be similar to some component movements occurring in actual earthquakes. It is needless to remark that both pulsatory oscillations and micro-tremors form interesting subjects of study, especially in connection with local earthquakes.

Tokyo. Jan., 1908.

# Omori Tromometer Diagram. Hitotsubashi (Tokyo); July 6, 1907.

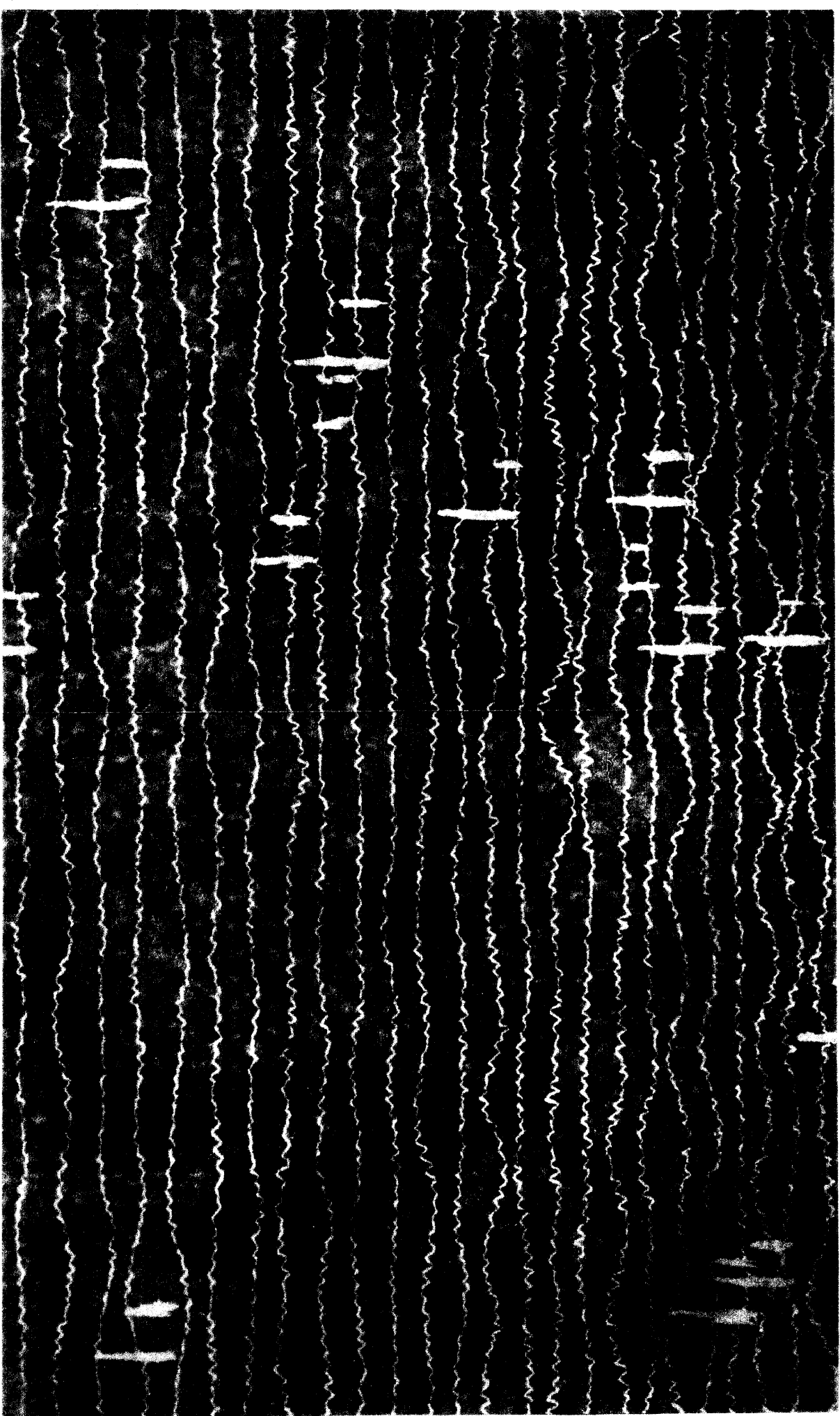
PL 1

EW Component; Pendulum Period = 19 sec.  
Magnification = 800. (Original Multiplication = 100).



Omori Tremor Recorder Diagram, showing Micro-Tremors.  
 Magnification=2,400. (Original Multiplication=300). Pendulum Period=4.7 sec.

Hongo (Tokyo), Jan. 23, 1908.  
 EW Component.  
 Slower movements are pulsatory oscillations.



0 second 5 10 15 20 25 second

Time scale.

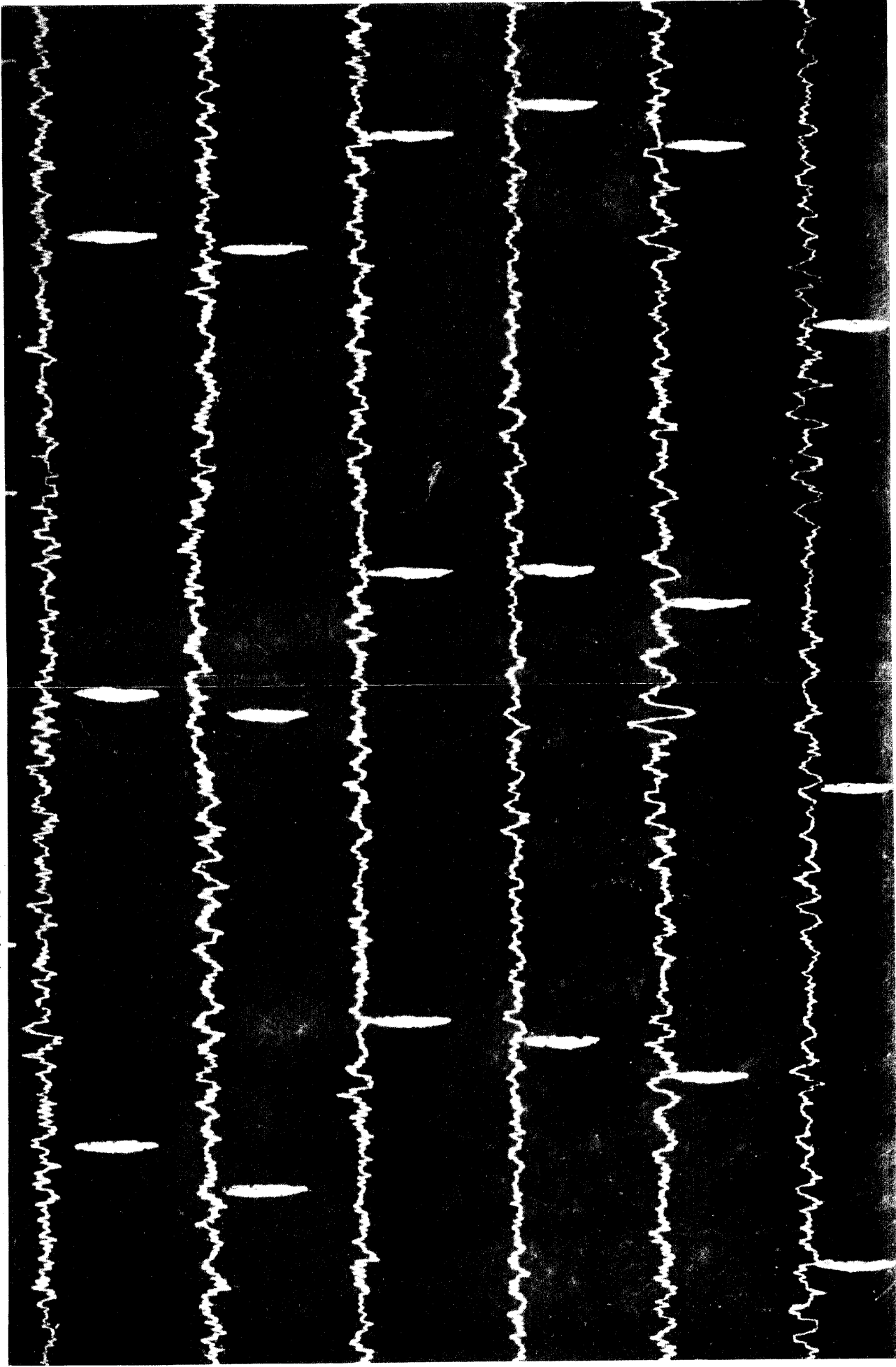
Omori Tremor Recorder Diagram, showing Micro-Tremors.

Magnification=700. (Original multiplication=90).

Pendulum Period=4 sec.

Osaka. Dec. 28, 1907.

NS Component.



Slow superposed movements are pulsatory oscillations.

Time scale : 1 interval=1 minute.