three sets of horizontal pendulum seismographs, whose sensibility to tilting and multiplication of horizontal motion were so arranged as to separate the horizontal motion from the tilting of the ground. The result so far obtained is that in the ordinary small and strong earthquakes, occurring so often in Tokyo, there is no tilting motion, or if any, not one sufficiently large to be recorded by means of ordinary seismographs.*

V. Pulsatory Oscillations.

28. *Pulsatory oscillations.*—Denote those small slow oscillations of the ground, whose origin is not seismic. Their average periods and ranges of motion in 70 cases between July 1898 and Dec. 1899 are collected in the following Table. These are not of course exhaustive, the measurements having only been made in so far as these movements occurred in the diagrams which contained earthquakes.

* A detailed account of these observations is given by the present Author in Vol. XXXII of the Reports (Japanese) of the Earthquake Investigation Committee.

TABLE XI.—AVERAGE PERIOD OF PULSATORY OSCILLATIONS.*

1898.

Day. \ Month.	VII.	VIII.	IX.	X.	XI.	XII.
	s	s	s	s	s	s
1			5,3			
2						
3						
4			3,9			
5						
6			5,8			
7					4,2	6,7
8						
9						
10						
11						
12						
13						3,9
14				6,8	5,6	
15					4,5	
16						
17						
18						
19						
20						
21						
22						
23						
24						
25	4,8					
26						
27						4,0
28					4,2	
29						
30						
31						4,4

* The max. range of motion was in each component 0,16 mm.

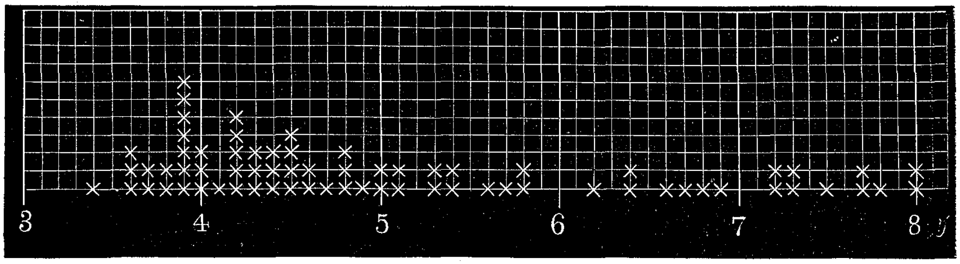
TABLE XI.—Cont.

1899.

Month. / Day.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.
	s	s	s	s	s	s	s	s	s	s	s	s
1												
2									3,6			
3			4,5						4,4			
4					3,6					6,4		
5								6,6		6,9		
6		4,5	7,7							7,2	4,3	
7			6,4				6,2	5,1		7,5		
8										{8,0		
9				3,7						{4,5		
10						4,3						
11		7,8					5,1		4,6			
12		3,9										
13			7,2									
14	4,8											3,9
15			3,8	3,7								
16			5,3									
17			4,0									
18				5,0				4,2				
19												
20		5,8										
21	3,9								5,7		3,9	
22	4,2	7,3										
23				4,0					8,0			
24			4,3	3,6								
25			4,9				3,9					
26			7,3									
27	4,1											
28									3,4			4,3
29							3,8			4,6		
30												{7,7
31												{5,0

It will be seen from the above table that the average period of the pulsatory oscillations varied between 3,4 s and 8,0 s ; periods of 3,9 s to 4,5 s occurring most frequently. The frequencies of the several periods are diagramatically shown in the accompanying figure.

Diagram showing the frequency of the different periods of pulsatory oscillations.



29. The max. 2a of the pulsatory oscillations within the time interval in question was 0,16 mm. in each component, which occurred on Oct. 7th, 1899, the average period being 8,0 s. The EW component diagram for Oct. 6th–7th is given in Pl. XIV. The pulsatory oscillations were in this case doubtless caused by disturbances in the atmosphere, which occasioned the remarkable sea-waves on the after-noon of the 7th along almost the whole coast of the Japanese Islands. It is, however, to be noted that pulsatory oscillations were already very strong on the 6th, although on that day it was almost perfectly calm over Shikoku and the Main Island. The lowest barometric pressure was 714,5 mm., observed at Nagatsuro (province of Izu) on the 7th at 2 p.m. The weather map of Oct. 6th-7th is given in Pl. XVIII.

30. The most remarkable storm of pulsatory oscillations which I have so far observed occurred on Nov. 17th–18th, 1900, the max. 2a having reached 0,65 mm. in each component. The average period was 6,8s. The EW component diagram is given in Pl. XV

This storm of pulsatory oscillations was also evidently caused by disturbances in the atmosphere, strong winds having prevailed on the

17th over the whole country. The barometric depression was, however, in this case not very deep, the lowest reading being 743 mm. observed at Shiomi-saki (southern extremity of the province of Kii) on the 17th, 2 p.m. The weather chart is given in Pl. XIX.

31. *On the nature of the pulsatory oscillations.*—The pulsatory oscillations, which are in no essential way different from the vibrations constituting the 1st preliminary tremor and the end portion of a distant earthquake, seem to be horizontal movements and not tiltings of the ground. For the considerations bearing on this point the reader is referred to my paper on horizontal pendulums published in Vol. XI. of the Jour. Coll. Sc. Imp. Univ. Tokyo. The chief characteristic points of these movements, as observed in Tokyo, are the following:—

1. Pulsatory oscillations occur more frequently in winter than in summer.

2. Pulsatory oscillations continue generally for several days, there being no dependence of the frequency on the time of day.

3. The average period remains generally constant for several hours, not depending much on the amplitude.

4. The average period varies but little, the least value being 3,4 s. and the greatest value 8,0 s.

5. The direction of motion changes constantly, and each horizontal component shows a series of alternations of maximum and minimum groups ; the motion is always on the whole equal in the two horizontal components. As additional illustrations, I give in Pls. XVI and XVII the EW component diagrams of the pulsatory oscillations on Nov. 18th–19th, 1900 ; the average period being 6,8s and the max. 2a being 0,25 mm. in each component.

The wave-length of pulsatory oscillations.—The wave-length of pulsatory oscillations seems to be much longer than those of the quick-period vibrations of an earthquake which constitute the ordinary seismic shocks and which are most efficient in producing damage, as may be inferred from the comparison of the observations at the Seismological Institute in the Imperial University, Hongo, and at the Seismological Observatory at Hitotsubashi. The distance between the two places is only 2,29 km.

At Hongo the ground is high and consists of hard clay, while at Hitotsubashi it is low and very soft, and consequently the amplitude of earthquake motion, as registered by ordinary seismographs is two or three times greater at the latter place than at the former.* In fact it is well known that earthquakes cause very much greater damage in low soft country than on a hill or hard high ground. With respect to pulsatory oscillations, however, no such peculiarity is found, the amplitude and the period being always the same at Hongo and Hitotsubashi. This fact can only be explained by supposing the wave-length of the pulsatory oscillations to be comparatively very great. If we assume the velocity of transit of pulsatory oscillations to be the same as that of the ordinary surface transit of earthquake motion, namely, 3,3 km. per sec., the wave-length of pulsatory oscillations would vary between

$$3{,}4^{s} \times 3{,}3^{km} = 11{,}2 \text{ km.}$$

$$\text{and} \quad 8{,}0 \times 3{,}3 = 26{,}4 \text{ ,,}$$

Pl. XVII gives the Hitotsubashi EW component diagram of the pulsatory oscillations on Nov. 18th–19th, 1900. The motion will be seen to be equal to the corresponding Hongo diagrams given in Pl. XVI. (The multiplication of the Hitotsubashi instrument is 8,2, while that of the Hongo instrument is 10).

* See the late prof. S. Sekiya's paper on the earthquake measurement in Tokyo. Jour. Sc. Coll. Imp. Univ. Tokyo. Vol. II.

Relation of pulsatory oscillations and the formation of the ground.—As stated above, the phenomena of pulsatory oscillations do not seem to vary within a small area, such as Tokyo. When considered, however, with respect to widely distant localities, there is great difference in the frequency as well as the intensity of these movements. Thus in Tokyo, pulsatory oscillations occur very often and have not seldom quite large amplitude. On the other hand, the simultaneous horizontal pendulum observations at Miyako Meteorological Observatory (in the province of Rikuchu), Arima (in the province of Settsu), and the Kyoto Imperial University show very few and very slight traces of pulsatory oscillations. I may here remark that Tokyo lies on the extensive Musashi plain, but the three above named stations are situated respectively on a small promontary of a paleozoic formation, among granite mountains, and in a valley surrounded by granite mountains.

The period of pulsatory oscillations.—Since the period of pulsatory oscillations varies little, and especially since the period (average) remains generally constant for several successive hours, it may be supposed that these movements represent the proper vibrations of certain portions of the earth's crust, such as the plain of Musashi. In fact there is no reason to suppose that the ground, even when not disturbed by earthquakes, is perfectly at rest. On the contrary it would be more general to assume that the different portions of the earth's crust are continually executing greater or less movements of some sort; and, if so, the periods ought to be determinable in each case from the geotectonic circumstances of the ground.