XI. Pulsatory Oscillations.

§ 16. A short note on the *pulsatory oscillations* observed at Hongō in 1898-1899 has been given in the *Publications*, No. 5 (pp. 51-57), according to which the average period of these movements varied between 3.4 and 8.0 sec., that of 3.9 to 4.5 sec. occurring most frequently. A careful examination of the horizontal pendulum diagrams shows, however, that the pulsatory oscillations consist, in most cases, essentially of the vibrations with a period of about 4 sec., more or less mixed up with those of a period of about 8 sec. The vibrations of 4 second period occur very frequently, but cases are not wanting, where the vibrations of the 8 seconds period predominate almost exclusively. Again there are sometimes cases, in which the two kinds of vibrations occur in different parts of one and the same diagram. The following are some of the instances of this nature.

Jan. 24-25, 1900. Till about 2 p.m. on the 24th, the pulsatory oscillations had essentially an average period of 4,4 sec. After 2 p.m., the principal average period was 7,1 sec., the max. 2a being 0,05 mm.

Feb. 17-18, 1900. On the morning of the 18th, the average period was 3,8s; while, on the 17th, it was 8,1 sec.

Feb. 20-21, 1900. Pulsatory oscillations of an average period of 8,1 sec., occurred till about 9 p.m. in the evening of the 20th, while those of an average period of 4,4 sec. occurred throughout after that hour.

Nov. 6-7, 1900. Till about 1 a.m. of the 7th, the motion was uniform and had an average period of 7,5 sec. (max 2a=0,06mm). During the rest of the morning of the same day, the average period was 3,9 sec. (max. 2a=0,06mm.)

The following example relates to a record from the 120-times magnification tromometer and is given for the sake of reference:—

Nov. 25-26, 1900. The diagram from the tromometer indicated,

till about 6p.m. of the 25th, the vibrations of an average period of 3.5 sec. (max. $2a=0.008$ mm), more or less grouped into movements of a slower period. Thereafter the motion became uniform and had an average period of 6.9 sec. (max. $2a=0.008$ mm). On account of the smallness of the amplitude, the diagram from 0-times magnification instruments only indicated the slower vibrations.

§ 17. Table XXVII gives the average period and the maximum range of motion in the 46 cases observed in 1900 at Hitotsubashi. 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. The average period was each time deduced from 100 or 200 consecutive vibrations.

TABLE XXVII.

LIST OF THE PULSATORY OSCILLATIONS, OBSERVED IN 1900 AT TOKYO. (**Hitotsubashi.**)

1900. Date and hour.	2a, or double amplitude.	Average period.
	mm	s
Jan. 20; 2½ p.m.	0,03	4,6
„ 21; 1 a.m.	(Small)	5,1
„ „ ; 6 p.m.	„	5,0
„ „ ; 7½ p.m.	„	4,6
„ 24; 3½ p.m.	„	4,4
„ „ ; 5½ p.m.	0,05	7,1
„ 30; 9 a.m.	0,04	4,1
„ „ ; 11 p.m.	(Small)	5,1
Feb. 3; 7 p.m.	0,06	3,8
„ 5; 6½ p.m.	0,06	4,9
„ 17; 2 p.m.	(Small)	8,1
„ 18; Morning.	0,08	4,2
„ „ ; „	(Small)	3,8
„ 20; till 9 p.m.	„	8,1
„ „ ; after 9 p.m.	„	4,4
„ 24; Morning.	„	5,0
„ 26; 10 p.m.	0,05	3,8
March 1; 6½ a.m.	(Small)	4,4
„ 7; 7½ p.m.	0,04	3,4
„ 10; 2 a.m.	(Small)	3,5
„ 14; 11½ p.m.	„	4,2
„ 15; 6 a.m.	0,20	4,6
„ „ ; 6 p.m.	(Small)	5,5
„ 16; 5 a.m.	„	5,2
„ 26; 7 a.m.	0,06	4,4
„ 28; 7½ p.m.	0,05	4,0
„ 29; 2 p.m.	(Small)	3,8
April 1; 9 p.m.	0,11	5,6
„ 20; 8 a.m.	(Small)	4,4
„ „ ; 9½ p.m.	0,14	4,5
„ 25; 4 p.m.	0,05	4,0
May 5; 11 p.m.	(Small)	4,3
„ 15; 6 a.m.	0,05	3,7
„ 30; 1½ p.m.	0,03	3,7
Aug. 25; 11½ p.m.	0,04	5,3
Sept. 18; 11 a.m.	(Small)	5,7 (?)
„ 24; 4 a.m.	0,08	4,5
Oct. 8; 3 a.m.	(Small)	3,8
„ 10; 1 p.m.	0,04	4,2
„ 16; Noon.	0,03	3,9
Nov. 1; 9¾ a.m.	0,09	3,8
„ 7; till 1 a.m.	0,06	7,5
„ „ ; after 1 a.m.	0,06	3,9
„ 19–20;	0,06	9,3
Dec. 2; 4–5 a.m.	(Small)	3,9
„ 8; Morning.	„	5,1

From the above table, it will be seen that in 41 out of the 46 cases, the average period varied between 3,4 and 5,7 sec., giving a mean value of 4,4 sec. ($=Q_1$). In the remaining five cases, the average period varied between 7,1 and 9,3 sec., giving a mean value of 8,0 sec. ($=Q_2$). It thus seems probable that the pulsatory oscillations are essentially composed of two series of vibrations, whose periods are respectively about 4 sec. and 8 sec.; large pulsatory movements, which are caused by very deep cyclones having generally the 8 seconds period. Some of the cases, in which the period is between 4 and 8 seconds, are probably produced by the mixing together of the two series of the movements. We may perhaps assume that the 8-seconds period vibration constitutes the fundamental oscillation proper to the Tōkyō plain, the 4-seconds period vibration being one of its harmonics.

§ 18. *On the period of vibration in the preliminary tremors of distant earthquakes.*

The result obtained in the above § seems to offer an explanation of the phenomena of the preliminary tremors of distant earthquakes so far as the period of vibration is concerned. Thus, according to § 5, there are two predominating periods, P_1 and P_2, in the 1st and 2nd preliminary tremors, as follows.

In 1st prel. tremor, ... $P_1=4,6$ sec.; $P_2=8,7$ sec.;

„ 2nd „ „ , ... ————; $P_2=8,5$ „ ;

these being the mean results deduced from the 82 distant earthquakes observed in 1900 at Hitotsubashi. The values of the two predominating periods, P_1 and P_2, found for Hongō, are nearly identical with those for Hitotsubashi, as follows.—

In 1st prel. tremor, ...$P_1=4,6$ sec.; $P_2=8,0$ sec.;

„ 2nd „ „ ..... ————; $P_2=8,1$ „ ;

these being the mean results deduced from the observations of 95 distant earthquakes, whose duration was between $\frac{3}{4}$ hour and several hours.* Taking together the results for Hitotsubashi and Hongō,

* See the *Publications*, No. 5, pp. 37-42.

we see that the principal periods of vibration in the 1st and the 2nd preliminary tremors are

$$\mathbf{P_1 = 4{,}6}\ \text{sec.},\quad \mathbf{P_2 = 8{,}3}\ \text{sec.},$$

which are practically identical respectively with the two periods of $Q_1 = 4{,}4$ sec. and $Q_2 = 8{,}0$ sec. found for the pulsatory oscillations in Tōkyō. As, further, the periods P_1 and P_2 do not depend on the distance of a seismic origin from the observing station, I conclude that the principal vibrations in the preliminary tremors of distant earthquakes and the pulsatory oscillations are identical phenomena; in other words, the period in the preliminary tremors do not depend on the nature of the disturbance at the seismic origin, but are characteristic to the region about Tōkyō. The formation of the vibrations, which constitute the preliminary tremors may be explained as follows:—The disturbance at the commencement of the 1st preliminary tremor, which has a transit velocity of some 14 km per sec., must travel along a layer at some distance below the earth's surface. (See § 43.) These would constitute a progressive source of disturbance and would communicate a sort of stress to the superimcumbent surface layer of the earth's crust in the region about a given station; the latter being, in consequence, thrown into its own proper oscillations, just as the waters of seas are thrown, by great sub-marine earthquakes or by atmospheric disturbances, into destructive waves, whose periods are the same as those of the waves existing at ordinary times and are constant at each given sea-coast place. By way of reference, we may note that the low atmospheric pressure always produces pulsatory oscillations of some intensity, which shows that the earth's crust, or rather a given district such as the plain of Musashi, is very easily thrown into movements.

§ 19. A glance at the diagrams of pulsatory oscillations shows that the motion consists always of alternations of maximum and minimum groups. This is exactly analogous to the phenomena of beats in acoustics. To take an example, in the great pulsatory oscillation storm on Nov. 17-19, 1900, (*the Publications*, No. 5), the

mean value of the intervals between the successive maximum displacements was about 1m 12 s. The motion may be regarded as the resultant of two series of simple harmonic movements of nearly equal amplitudes, whose period were 8 and 9 seconds respectively.

XII. The Preliminary Tremors of the Earthquake Motion.

(A) DISTANT EARTHQUAKES.

§ 20. In the *Publications*, No. 5, p.p. 61-66, I have discussed the relation between the durations of the preliminary tremors at a given station and the distance of the latter from the origin of disturbance. I am here going to consider again the same problem, with additional material recently obtained.

The following table contains the list of the observations of 15 large earthquakes of known origin, whose *spherical* distance (x) from Tōkyō varied between 2200 km and 14200 km. Of these earthquakes, which are arranged in order of the duration (y) of the *total* preliminary tremor, ten occurred in 1900-1902, while the other five took place in 1899 and have already been discussed in the *Publications*, No. 5. The relation between x and y is graphically illustrated in Fig. 4.