$$(7)\ldots\ldots\ldots x^{km} = \mathbf{14.42}\, y_1^{sec.} - \mathbf{148}^{km},$$
$$\text{for} \quad 40° < x < \text{about } 150°;$$

This formula, which is a revised form of that first given in the *Publications*, No. 5, may be regarded as being applicable to the observations made in Japan. Equation (4) given in the preceding § is to be regarded as expressing the approximate mean relation between the x and y_1 for different stations.

Chapter VIII. Periods of Vibration.

124. ***Quarto-Castello and Birmingham.*** By way of illustration let us examine the periods of vibration occurring in the Quarto-Castello and Birmingham diagrams, which were furnished by Stiattesi and Omori seismographs respectively (§§ 29 and 33). In the subsequent tables, the periods more frequently occurring are given in fat prints.

TABLE XXI. Periods of Vibration at Birmingham.

1st. prel. Tremor.	2nd prel. Tremor.	1st and 2nd Ph., P.P.	3rd Phase, Princ. Port.	4th Phase, Princ. Port.	End Portion.	Mean.
4.6 sec.	4.6 sec.	— sec.	— sec.	— sec.	— sec.	**4.6** sec.
7.1	—	7.5	—	—	—	**7.3**
—	9.7	9.9	—	9.7	10.4	**9.9**
12.0	—	—	—	12.3	—	**12.2**
—	15.5	—	—	14.7	14.3	**14.8**
—	—	18.8	17.9	—	16.7	**17.8**
—	—	—	31.4*	—	—	31.4*
—	—	36.6	—	—	—	36.6

(*Due to proper pendulum motion.)

TABLE XXII. Periods of Vibration at Quarto-Castello.

1st Preliminary Tremor.	2nd Preliminary Tremor.	1st and 2nd Ph. Princ. Portion.	3rd Phase, Princ. Portion.	Later Ph. of Princ. Port. End Portion.	Mean.
sec. **4.3**	sec. **4.8**	sec. 4.9	sec. —	sec. **4.9**	sec. **4.7**
6.4	—	—	6.9	—	**6.7**
9.1	**8.6**	**9.1**	**10.0**	9.1	**9.2**
—	11.1	—	—	12.1	**11.6**
—	—	—	**15.0**	**14.5**	**14.8**
—	—	—	—	**16.7**	**16.7**
—	—	—	—	**18.8***	**18.8**
—	—	—	26.6	—	26.6
—	—	29.8	—	—	29.8
—	—	50.0	—	—	50.0
—	54.5	—	—	—	54.5

Comparing Tables XXI and XXII, we see that nearly all of the different periods at Birmingham are to be found also at Qnarto-Castello. Again, from Table XXII it will be seen that the two periods of mean values of 4.7 and 9.2 sec. occurred in the successive phases of the Quarto-Castello seismogram. The two corresponding periods, whose mean values are 4.6 and 9.9 sec. respectively, also occurred in most of the different phases of the Birmingham seismogram.

125. ***Taihoku, Taichu, Tainan.*** Table XXIII gives the period (T) and the maximum range ($2a$) in each of the successive epochs of the earthquake motion registered at the three Formosan stations of Taihoku, Taichu, and Tainan (§§ 25, 26, and 27). The observations at theses places may be regarded as examples of the seismic records furnished by horizontal pendulums of comparatively short period.

TABLE XXIII. T and $2a$ observed at 3 Formosan Stations of Taihoku, Taichu, and Tainan. EW Component Seismograms.

	Taihoku.	Taichu.	Tainan.
[1st Preliminary Tremor.]			
	Duration = 6^m 6^s	Duration = 6^m 14^s	Duration = 6^m 15^s
	T = 1.07 sec. $2a$ = —	T = — $2a$ = —	T = — $2a$ = —
	2.10 „ —	— —	— —
	3.30 „ —	— —	— —
	4.3 „ 0.06 mm.	4.5 sec. 0.17 mm.	4.0 sec. 0.12 mm.
	— —	5.8 „ —	— —
	— —	— —	13.8 „ 0.08 „
[2nd Preliminary Tremor.]			
	Duration = 5^m 25^s	Duration = 5^m 10^s	——
	T = 4.5 sec. $2a$ = 0.1 mm	T = 4.9 sec. $2a$ = 0.33 mm	T = — $2a$ = —
	— —	10.2 „ 0.3 „	12.1 sec. 2.3 mm
	21 „ 0.1 „	— —	— —
[1st and 2nd Phases, Principal Portion.]			
	Duration = 4^m 35^s	Duration = 4^m 50^s	{2nd prel. Trem., 1st and 2nd Ph., Princ. Portion . . . . 9^m 46^s .
(i) During the first	..... 2^m 24^s	..... 2^m 9^s	.... . ——
	T = 4.4 sec. $2a$ = 0.08 mm	T = 4.4 sec. $2a$ = 0.23 mm	T = — $2a$ = —
	10.8 „ —	9.3 „ 0.73 „	— —
	41.2 „ 0.22 „	— —	— —
(ii) During the next	..... 2^m 11^s	..... 2^m 41^s	— —
	— —	4.6 sec. 0.23 mm	— —
	— —	6.8 „ 0.50 „	— —
	— —	10.0 „ 2.0 „	11.8 sec. 4.6 mm
	— —	16.5 „ —	15.3 „ —
	30 sec. 3.1 mm	— —	— —

	Taihoku.	Taichu.	Tainan.
[3rd Phase, Principal Portion.]			
	Duration = 5^m 30^s	Duration = 5^m 40^s	——
(i) During the first	..... 3^m 29^s	..... 1^m 44^s	.....3^m 8^s
	T = — $2a$ = —	T = 9.0sec. $2a$ = 12.8mm	T = 11.8sec. $2a$ = 13.8mm
	14.4sec. 11.9mm	— —	— —
(ii) During the next	..... 2^m 1^s	..... 3^m 56^s	
	5.7sec. —	5.0sec. 0.33mm	
	11.8 „ 2.05mm	8.9 „ 6.3 „	
	— —	14.8 „ 6.3 „	
[4th, etc., Phases, Principal Portion.]			
	——	..Duration = 3^m 5^s ..	..Duration = 6^m 2^s
	T = — $2a$ = —	T = 8.4sec. $2a$ = 1.2mm	
	— —	— —	T = 12.0sec. $2a$ = 6.8mm
	— —	22.3 „ —	
End Portion.			
	T = 6.6sec. $2a$ = —	T = 5.2sec. $2a$ = 0.17mm	— —
	11.6 „ 0.35mm	8.9 „ 0.5 „	— —
	— —	13.6 „ 0.17 „	T = 13.0sec. $2a$ = 5.6mm

According to the above table, there is between the three stations often a marked difference in the amplitudes corresponding to a given period, being obviously the effect due to the difference in the amount of friction and the stability of the " steady mass " in the three seismographs.

The following table gives the results obtained by taking together the analyses contained in the preceding; the $2a$ is the maximum value corresponding to a given period in the three stations.

TABLE XXIV. 3 Formosan Stations. Elements of Motion.

1st Prel. Trem. Dur. = $6^m\ 12^s$		2nd Prel. Trem. Dur. = $5^m\ 18^s$		1st and 2nd Ph., Princ. Port. Dur. = $4^m 43^s$		3rd Phase, Princ. Port. Dur. = $5^m 35^s$		4th Phase, Princ. Port. Dur. = —		End Portion. —	
T sec.	$2a$ mm.	T sec.	$2a$ mm.	T sec.	$2a$ mm.	T sec.	$2a$ mm.	T sec.	$2a$ mm.	T sec.	$2a$ mm.
1.07	—	—	—	—	—	—	—	—	—	—	—
2.1	—	—	—	—	—	—	—	—	—	—	—
3.3	—	—	—	—	—	—	—	—	—	—	—
4.3	0.17	**4.7**	0.33	**4.5**	0.23	**5.4**	0.33	—	—	**5.9**	0.17
5.8	—	—	—	6.8	0.50	—	—	—	—	—	—
—	—	11.2*	2.3	**10.0**	2.0	**9.9**	12.8	8.4	1.2	**10.3**	0.5
13.8*	0.08	—	—	—	—	11.8*	13.8	12.0*	6.8	13.3*	5.6
—	—	21.*	0.1	—	—	—	—	22.3	—	—	—
—	—	—	—	**15.9**	—	**14.6**	11.9	—	—	—	—
—	—	—	—	30.	3.1	—	—	—	—	—	—
—	—	—	—	41.2	0.22	—	—	—	—	—	—

(* Probably due to pendulum oscillations).

In the above table the periods given in fat letters are those meaned from the values for the two or all of the three different stations. The average values of these periods are as follows:—

4.96 sec.; (max. $2a = 0.33^{mm}$, in 2nd prel. trem., and 3rd phase of princ. port.)

9.70 „ ; (max. $2a = 12.8^{mm}$, 3rd ph. of princ. portion).

15.3 „ ; („ $= 11.9^{mm}$, „ „ .)

Thus the period of 4.96 sec. occurred throughout the different portions of the earthquake motion, the period of 9.7 sec. occurring in the principal and end portions. The longest periods of 30 and 41.2 sec. occurred in the 1st and 2nd phases of the principal portion. The vibrations of average periods of 9.7 and

15.3 sec. had the greatest $2a$'s respectively of 12.8 and 11.9 mm, while those with the periods of 4.96 sec. had a much smaller $2a$ of 0.33 mm. The vibrations of the macroseismic nature, or those of T=1.07, 2.1, and 3.3 sec., were very small.

The values of the different periods meaned from all the phases of the earthquake motion are given in the following table; the corresponding $2a$'s being the maximum ranges among the three stations.

T=1.07 sec.,	$2a$ = — mm.
2.1	—
3.3	—
4.96	0.33
6.3	0.50
9.7	12.8
12.4	13.8
15.3	11.9
21.7	0.1
30.0	3.1
41.2	0.22

That vibrations of poriods respectively equal to the two last of the above series have been registered by the short-period horizontal pendulums indicates the existence of slow movements with large amplitude.

126. ***Note on the Horizontal Pendulum Observations of Earthquakes at Taichu, in 1903 and 1904.*** For the sake of reference, I give here a few remarks on the period of vibration at Taichu based on the examination of the eastwest diagrams of 12 earthquakes observed at the latter place between Jan. 1903, and Sept. 1904. Each of these earthquakes was of a comparatively near origin, and the duration of the total preliminary tre-

mor varied between 11 and and 31 sec.; the total earthquake duration varying from $7\frac{1}{2}$ to 22 min.

The average complete periods in the different phases of the earthquake motion were as follows:—

Preliminary Tremor.	*Principal Portion.*	*End Portion.*
sec.	sec.	sec.
0.69	3.4	3.3
4.6	**4.97**	**4.95**
8.0	7.6	
	10.3	

Thus the period of vibration most frequently happening throughout the three principal divisions of the earthquake motion varied between 4.6 and 4.97 sec., the general mean value being 4.9 sec. This is evidently identical with the period P_1, found from the seismograms obtained in Tokyo; the value of P_1 meaned from the observations at Hongō and Hitotsubashi (both in Tokyo) being 4.6 sec. Further, the period P_1 is identical with the period Q_1, of the "pulsatory oscillations," at Tokyo, whose mean value was found to be 4.4 sec. (See the "Publications of the Earthq. Inv. Comm.," Nos. 5 and 13.) Hereby it is interesting to note that the horizontal pendulum diagrams obtained at the town of Taitō, which is on the eastern coast of Formosa, indicates pulsatory oscillations of an average period of about 5.0 sec.

The horizontal pendulum employed at Taichu was unable, on account of the shortness of its period of free oscillation (=15sec.), to satisfactorily register vibrations of much longer period. On this very account, however, I was enabled to recognize the existence in the *principal portion* of vibrations of P_1 period. That the long-period horizontal pendulums at Tokyo did not usually show, in cases of large earthquakes, vibrations of P_1 or P_2 period in the principal portion, is probably due to the predominance of

the record of slow period movements, the short period ones being thereby obscured.

127. ***Ōsaka.*** Table XXV gives the periods occurring in the different phases of earthquake motion at Ōsaka (§ 22).

TABLE XXV. Periods of Vibration at Ōsaka.

	1st Prel. Trem.	sec. 4.6	sec. 7.8	sec. —	sec. —	sec. —	sec. —	sec. 23.8	sec. —	sec.
	2nd. Prel. Trem.	—	—	—	—	—	20.2	25.5	32.5 30.0	
Princ. Port.	1st, 2nd Ph.	—	—	—	—	—	21.7	—	—	28.3*
	3rd Phase.	—	—	11.3	—	—	—	24.2	—	26.8*
	4th „	—	—	10.5	—	—	22.2	—	—	
	5th „	—	—	10.2	14.4	18.5	—	—	—	
	End Portion.	—	—	10.8	14.2	—	21.7	—	—	
	W_2	—	—	—	—	18.5	20.4	25.1	—	
	W_3	—	—	—	—	18.5	—	—	—	
	Mean	**4.6**	**7.8**	**10.7**	**14.3**	**18.5**	**21.2**	**24.7**	32.5 30.0	27.6

(*Proper pendulum oscillations).

The periods of vibration in the W_3 motion was 18.5 sec., being equal to that of the most active part in W_2.

From Table XXV, it will be seen that the periods of average values of 21.2 and 24.7 sec. occurred in the different phases of the earthquake motion as well as in the W_2 wave, or the movement propagated along the major arc. Again, all the different periods occurring at Ōsaka can be identified in the seismograms obtained at the stations considered in the preceding §§.

128. ***Comparison of the NS Component Records at Tokyo and Kobe.*** The following table gives a comparison of the elements

of motion in the NS component recorded at Tokyo and Kobe, based on the analyses given in §§ 15 and 23.

TABLE XXVI. Periods of Vibration in the NS Component at Tokyo and Kobe. (*....Peudulum Oscillation.)

Tokyo.		Kobe.	
[1st Preliminary Tremor.]			
Duration = $7^m\ 6^s$		Duration = $7^m\ 0^s$	
$T = 5.2^{sec.}$	$2a = 0.14^{mm}$	$T = 4.4^{sec.}$	$2a = 0.05^{mm}$
—	—	11.5	—
15.8	0.22	—	—
20.0	0.43	—	—
—	—	—	—
29.8	0.43	—	—
[2nd Preliminary Tremor.]			
Duration = $8^m\ 20^s$		Duration = $5^m\ 44^s$(?)	
T = —	$2a$ = —	T = —	$2a$ = —
—	—	$30.0^{sec.}$*	3.0^{mm}
$33.5^{sec.}$	1.63^{mm}	—	—
40.4	3.53	—	—
45.0*	3.95	—	—
55.2	—	—	—
[Principal Portion.]			
$10.7^{sec.}$	1.7^{mm}	$10.7^{sec.}$	0.19^{mm}
19.5	1.3	18.2	2.0
22.8	0.58	23.5	1.1
—	—	28.3*	8.2

Tokyo.		Kobe.	
—sec.	—mm	33.0sec.	2.7mm
—	—	40.3	4.8
44.3*	8.3	—	—
—	—	55.8	2.0
[End Portion.]			
12.9sec.	0.3mm	13.1sec.	—mm
26.2	—	—	—
[W_2 Motion.]			
12.3sec.	—mm	—	—
18.8	0.12	—	—
25.8	0.10	—	—
29.5	—	—	—
45.0*	0.10	—	—

The following table has been formed from a comparison of the periods at the two stations as given in the preceding one.

TABLE XXVII. Mean Periods occurring at Tokyo and Kobe.
NS Component.

1st preliminary Tremor.		2nd Preliminary Tremor.		Principal Portion.		End Portion.		W_2	
T	$2a$	T	$2a$	T	$2a$	T	$2a$	T	$2a$
sec.	mm	sec.	mm	sec.	mm	sec.	mm	sec.	mm
4.8	0.14	—	—	—	—	—	—	—	—
11.5	—	—	—	**10.7**	1.7	—	—	—	—

1st Preliminary Tremor.		2nd Preliminary Tremor		Principal Portion.		End Portion.		W_2	
T sec.	$2a$ mm	T sec.	$2a$ mm	T sec.	$2a$ mm	T sec.	$2a$ mm	T sec.	$2a$ mm
—	—	—	—	—	—	**13.0**	0.3	12.3	—
15.8	0.22	14.8	—	—	—	—	—	—	—
20.0	0.43	—	—	**18.9**	2.0	—	—	**18.3**	0.12
—	—	—	—	**23.2**	1.1	—	—	—	—
—	—	—	—	—	—	26.2	—	25.8	0.10
29.8	0.43	**30.3***	3.0	**28.3**	8.2	—	—	29.5	—
—	—	**33.5**	1.63	33.0	2.7	—	—	—	—
—	—	40.4	3.53	**40.3**	4.8	—	—	—	—
—	—	45.0*	3.95	44.3*	8.3	—	—	45.0*	0.10
—	—	55.2	—	55.8	2.0	—	—	—	—

In the above table, the amplitude corresponding to any given period is the maximum among those for the two places.

The values of the different periods meaned through all the different portions of the earthquake motion, and the corresponding maximum $2a$'s, are given in the following table; the values of the periods evidently due to the pendulum oscillations being excluded.

$T=$ **4.8** sec.,	$2a=0.14$ mm
11.1	1.7
12.7	0.3
15.3	0.22
19.2	2.0
24.6	1.1
29.4	0.43
33.3	2.7
40.2	4.8
55.5	2.0

Many of these periods will be found to exist also in the Ōsaka and Formosa EW records, as well as in the Birmingham and Quarto-Castello seismograms. It is to be specially noted that the two last in the above series, namely, the long periods of 40.2 and 55.5 sec. occurred respectively in the Formosa and Quarto-Castello records.

129. ***American and Mexican Stations.*** Tables XXVIII and XXIX give respectively the periods and the corresponding max. movements at the American and Mexican stations.

TABLE XXVIII. Periods and Range of Vibration.
EW Component.

Phase of motion.	Cheltenham.		Tacubaya.		Mean.	
	T sec.	$2a$ mm	T sec.	$2a$ mm	T sec.	$2a$ mm
1st Prel. Tremor.	7.8	(small)	7.7	—	7.8	—
	12.3	0.05	14.2	—	13.3	0.05
2nd Prel. Tremor.	—	—	11.7	(small)	11.7	—
	14.4	0.05	—	—	14.4	0.05
	—	—	32.2	0.10	32.2	0.10
	41.0	0.10	—	—	41.0	0.10
1st and 2nd Phases, Principal Portion.	64.0	0.12	—	—	64.0	0.12
	54.0	0.12	57.4	0.10	55.7	0.12
	45.5	0.12	45.8	0.10	45.7	0.12
	—	—	37.5	0.12	37.5	0.12
	30.0	0.08	—	—	30.0	0.08
	22.4	0.12	24.8	(small)	23.6	0.12
	15.2	(small)	—	—	15.2	—

Phase of motion.	Cheltenham.		Tacubaya.		Mean	
	T sec.	$2a$ mm	T sec.	$2a$ mm	T sec.	$2a$ mm
3rd Phase,	19.7 *	0.83	18.1 *	0.15	—	—
Principal Portion.	—	—	22.5	0.12	22.5	0.12
4th, etc., Phases,	15.6	0.21	17.5 *	—	15.6	0.21
Principal Portion.	20.2 *	0.36	21.2	—	—	—
W_2	18.6 *	0.28	18.0 *	0.10	—	—

TABLE XXIX. Periods and Range of Vibration. NS Component.

Phase of motion.	Cheltenham.		Washington.		Tacubaya.		Mean.	
	T sec.	$2a$ mm.	T sec.	$2a$ mm.	T sec.	$2a$ mm.	T sec.	$2a$ mm.
1st Prel. Tremor.	—	—	4.3	—	—	—	4.3	—
	7.1	—	6.3	—	8.9	—	7.4	—
	12.6	—	—	—	—	—	12.6	—
	30.3	—	—	—	—	—	30.3	—
	40.7	0.15	—	—	—	—	40.7	0.15
2nd Prel. Tremor.	8.4	—	—	—			8.4	—
	11.2	—	—	—			11.2	—
	—	—	21.4	—			21.4	—
	24.6	0.06	—	—			24.6	0.06
	30.7	0.09	28.0	—			29.4	0.09
	—	—	39.5	—			39.5	—
	46.0	0.07	—	—			46.0	0.07

* Pendulum oscillations.

Phase of motion.	Cheltenham.		Washington.		Tacubaya.		Mean.	
	T	$2a$	T	$2a$	T	$2a$	T	$2a$
	sec.	mm	sec.	mm	sec.	mm	sec.	mm
	62.3	0.14	—	—	—	—	62.3	0.14
	48.0	0.09	49.5	0.05	—	—	48.8	0.09
	—	—	44.3	—	45.0	0.10	44.7	0.10
1st and 2nd Phases,	—	—	—	—	40.3	0.10	40.3	0.10
Princ. Portion.	29.8	0.24	—	—	—	—	29.8	0.24
	—	—	27.8	0.08	—	—	27.8	0.08
	25.8	—	—	—	—	—	25.8	—
	14.1	—	—	—	—	—	14.1	—
	17.5*	2.12	15.1	—	15.8*	0.30	15.1	—
3rd Phase, Princ. Portion.	21.2	—	19.4*	1.2	—	—	21.2	—
	—		—		24.0	0.12	24.0	0.12
4th Phase., Princ. Portion., and End Portion.	16.1*	0.21	—	—	16.3*	—	16.2*	0.21
	21.6	0.05	—	—	—	—	21.6	0.05
	29.0	0.06	27.0	—	—	—	28.0	0.06
	22.8	0.19	21.9	—	—	—	22.4	0.19
W_2	18.5	0.06	—	—	19.4	0.48	19.0	0.48
	—	—	16.5	—	16.0*	0.15	16.3*	0.15
	—	—	13.5	—	—	—	13.5	—

The NS and EW components correspond, in the cases of the American and Mexican stations, approximately to the longitudinal and transverse waves, and, as will be seen from Tables XXVIII and XXIX, the vibrations in the principal portion and W_2 motion was markedly greater in the NS component. Similar periods, however, seem to occur in the two horizontal components, the notable examples being slow periods of 40 to over 60 seconds.

The mean periods of vibration deduced from the EW and NS component observations at the three stations in question are given in Table XXX; the $2a$'s being each the corresponding maximum range among the different components.

TABLE XXX. Periods and Range of Vibration. EW and NS. Cheltenham, Washington, Tacubaya.

Phase of motion.	T	$2a$.	Phase of motion.	T	$2a$.
	sec.	mm		sec.	mm
	4.3	—	3rd Phase,	15.1	—
1st Preliminary	**7.6**	—	Principal Portion.	**21.9**	0.12
Tremor.	**13.0**	0.05		24.0	0.12
	30.3	—			
	40.7	0.15	4th, etc. Ph., P.P.	15.6	0.21
				16.2 *	0.21
	8.4	—	End portion.	21.6	0.05
	11.5	—			
	14.4	0.05			
	21.4	—		28.0	0.06
2nd Preliminary	24.6	0.06		22.4	0.19
Tremor.	29.4	0.09	W_2	19.0	0.48
	32.2	0.10		16.3 *	0.15
	40.3	0.10		13.5	—
	46.0	0.07			
	63.2	0.14			
	55.7	0.12			
	48.8	0.09			
	45.2	0.12			
1st and 2nd Phases,	40.3	0.10			
Principal Portion.	37.5	0.12			
	29.9	0.24			
	27.8	0.08			
	24.7	0.12			
	14.7	—			

Finally taking the averages of the different periods from the successive phases of motion, we obtain :—

T =	$2a$ =
4.3 sec.	— mm
7.9	—
11.5	—
14.3	0.05
21.2	0.48
24.1	0.19
31.1	0.24
37.5	0.12
40.4	0.15
46.3	0.12
55.7	0.12
63.2	0.14

Thus, in this case we have a long period of 63.2 sec., all the other periods, ranging from 4.3 sec. up to 55.7 sec., being also found at some or other of the stations considered in the preceding §§.

130. ***Periods of Vibration at the different Places.*** From the foregoing §§ it will be seen that many periods of vibration were common to several of the stations. To compare generally the periods occurring at different places, I give, in the four tables, XXXI to XXXIV, the period (T) and the corresponding range ($2a$) in the different phases of the earthquake motion observed at 10 stations, as follows :—

Table XXXI ....Tokyo.
„ XXXII ....Ōsaka, Kōbe, Tadotsu.
„ XXXIII....Birmingham, Quarto-Castello.
„ XXXIV ....Potsdam, Leipzig, Göttingen, Upsala.

Besides these, Tables XXIV and XXX, already given, contain

the elements of motion in question, respectively for Taihoku, Taichu, and Tainan, and for Cheltenham, Washington, and Tacubaya. The observation of the periods at the above named 16 places are more complete than that at the others.
(*....pendulum motion.)

TABLE XXXI. Periods of Vibration and Max. $2a$. ***Tokyo.***

Phase of motion	E W § 14.	E W Tromometer. § 20.	E W Tromometer. Centr. M. O.	N S.	Vertical.	**Mean.**
	T $2a$ sec. mm.	T $2a$ sec. mm.	T $2a$ sec. mm.	T $2a$ sec. mm.	T $2a$ sec. mm.	T $2a$ sec. mm.
1st Preliminary Tremor.	4.6 0.20	4.4 0.25	4.4 0.17	5.2 0.14	4.2 —	4.5 0.25
	8.0 0.30	8.6 0.33	7.4 0.22	—	7.3 0.31	7.8 0.33
	—	—	—	15.8 0.22	—	15.8 0.22
	—	—	—	20.0 0.43	—	20.0 0.43
	24.7 0.57	—	—	—	—	24.7 0.57
	—	—	—	29.8 0.43	—	29.8 0.43
2nd Preliminary Tremor.	—	4.8 0.21	—	—	—	4.8 0.21
	9.0 Small	8.8 0.61	9.1 1.06	—	—	9.0 1.06
	—	11.8 1.05	—	—	—	11.8 1.05
	—	—	—	23.1 2.33	—	23.1 2.33
	26.5 0.97	—	—	—	—	26.5 0.97
	—	—	—	33.5 1.63	—	33.5 1.63
	37.1 4.50	—	—	—	—	37.1 4.50
	—	—	—	40.4 3.53	—	40.4 3.53
	—	—	—	45.3 3.95	—	45.3 3.95
	49.7 5.80	—	—	—	—	49.7 5.80
	54.0 —	—	—	55.2 —	—	54.6 —
	86.0 2.27	—	—	—	—	86.0 2.27

TABLE XXXI. *Cont.*

Phase of motion	E W § 14.	E W Tromometer. § 20.	E W Tromometer. Centr. M. O.	N S.	Vertical.	**Mean.**
	T 2*a* sec. mm.	*T* 2*a* sec. mm.	*T* 2*a* sec. mm.	*T* 2*a* sec. mm.	*T* 2*a* sec. mm.	*T* 2*a* sec. mm.
	—	9.3 0.40	8.1 0.23	—	—	8.7 0.40
	11.3 0.33	—	—	—	—	11.3 0.33
	—	16.8 0.53	—	—	—	16.8 0.53
1st and 2nd	—	—	—	—	22.3 0.13	22.3 0.13
Phases,	27.6 6.24	29.0 0.66	—	—	29.7 0.28	28.8 6.24
Principal	—	38.5 0.58	36.8 0.20	—	—	37.7 0.58
Portion.	—	—	—	42.5 —	—	42.5 —
	—	—	—	47.8 6.65	45.2 0.07	46.5 6.65
	53.0 10.8	53.0 0.36	—	—	—	53.0 10.80
	59.0 1.30	—	—	—	—	59.0 1.30
	10.8 3.67	—	10.0 2.90	10.3 1.70	—	10.4 3.67
3rd Phase,	16.8 2.40	—	—	—	14.1 0.29	15.5 2.40
Princ.	20.5 —	21.0 *	23.8 —	23.0 —	—	22.1 —
Portion.	—	34.8 Large	—	—	—	34.8 Large
	—	—	—	42.5 2.70	—	42.5 2.70
	—	8.2 0.24	—	—	—	8.2 0.24
4th etc.	11.3 0.80	—	11.1 2.20	10.8 1.40	11.6 —	11.2 2.20
Phases,	13.2 0.72	12.1 1.67	—	12.8 0.30	—	12.7 1.67
Princ.	—	—	15.2 0.78	—	15.7 —	15.5 0.78
Portion;	—	—	— —	19.5 1.30	—	19.5 1.30
End Portion.	—	—	—	22.6 0.58	—	22.6 0.58
	—	—	—	26.2 —	—	26.2 —

TABLE XXXII. Periods and Max.2a. ***Ōsaka, Kōbe, Tadotsu.***

Phase of motion.	Ōsaka (EW)		Kōbe (NS)		Tadotsu (EW)		**Mean.**	
	T sec.	$2a$ mm	T sec.	$2a$ mm	T sec.	$2a$ mm	T sec.	$2a$ mm
1st Preliminary Tremor.	4.6	0.53	4.4	0.05	4.7	—	4.6	0.53
	7.8	Small	——		——		7.8	—
	——		11.5	—	10.4	—	11.0	—
	23.8	1.05	——		24.4 *	0.20	24.0	1.05
2nd Preliminary Tremor.	——		——		14.8	—	14.8	—
	20.2	1.58	——		——		20.2	1.58
	25.5	1.69	——		——		25.5	1.69
	30.0	—	30.0*	3.0	31.5	0.86	30.9	3.00
	32.5	2.53						
	——		——		36.5	0.14	36.5	0.14
1st and 2nd Ph., Princ. Portion.	21.7	1.58	——		19.0	—	20.4	—
	28.3*	4.5	——		——		28.3	4.50
	——		34.0	0.48	——		34.0	0.48
	——		40.3	4.8	39.4	1.4	39.9	4.80
	——		55.8	2.0	——		55.8	2.00
3rd Phase, Princ. Portion.	11.3	—	——		——		11.3	—
	——		18.5	2.00	——		18.5	2.00
	24.2	2.25	——		——		24.2	2.25
	26.8*	11.7	28.3	8.20	28.0 *	Large.	27.7	11.70
	——		32.0	2.70	——		32.0	2.70
4th, etc. Phases, Princ. Portion; End Portion.	10.5	0.14	10.7	0.19	10.2	0.53	10.5	0.53
	14.3	0.63	13.1	—	13.6	0.27	13.7	0.63
	18.5	0.68	17.8	0.45	19.7	0.72	18.7	0.72
	22.0	1.73	23.5	1.10	——		22.8	1.73

TABLE XXXIII. Periods of Vibration and Max. $2a$.

Birmingham and Quarto-Castello.

Phase of motion.	Birmingham. (EW)		Quarto-Castello. (EW and NS)		**Mean.**	
	T sec.	$2a$ mm	T sec.	$2a$ mm	T sec.	$2a$ mm
1st Preliminary Tremor.	**4.6**	—	**4.3**	0.04	4.5	0.04
	7.1	—	6.4	0.02	6.8	0.02
	——		9.1	0.07	9.1	0.07
	12.0	0.035	——		12.0	0.035
2nd Preliminary Tremor.	4.6	—	**4.8**	0.04	4.7	0.04
	9.7	0.028	**8.6**	0.26	9.2	0.26
	——		11.1	0.25	11.1	0.25
	15.5	0.083	——		15.5	0.083
	——		54.5	0.51	54.5	0.51
1st and 2nd Phases, Principal Portion.	——		4.9	—	4.9	—
	7.5	—	——		7.5	—
	9.9	0.07	**9.1**	0.30	9.5	0.30
	18.8	0.16	——		18.8	0.16
	——		29.8	0.44	29.8	0.44
	36.6	0.24	——		36.6	0.24
	——		50.0	0.22	50.0	0.22
3rd Phase, Principal Portion.	——		6.9	0.034	6.9	0.034
	——		**10.0**	0.44	10.0	0.44
	17.9	1.56	**15.0**	0.63	16.5	1.56
	——		26.6	0.72	26.6	0.72
	31.4	2.03	——		31.4	2.03

Phase of motion.	Birmingham. (EW)		Quarto-Castello. (EW and NS)		**Mean.**	
4th, etc. Phases, Principal Portion; End Portion.	——		**4.9**	—	4.9	—
	10.1	0.04	9.1	0.38	9.6	0.38
	12.3	0.60	12.1	0.46	12.2	0.60
	14.5	0.25	**14.5**	0.57	14.5	0.57
	16.7	—	**16.7**	0.22	16.7	0.22
	——		**18.8** *	0.48	18.8*	0.48

TABLE XXXIV. Periods of Vibration and Max. $2a$.

Potsdam, Leipzig, Göttingen, Upsala.

Phase of motion.	Potsdam.		Leipzig.	Göttingen.	Upsala.	**Mean.**
	T sec.	$2a$ mm	T sec.	T sec.	T sec.	T sec.
1st Preliminary Tremor.	5.4	0.12	4.3	4.4	**4.4**	4.6
	——		7.9	**8.8**	**8.5**	8.4
	——		10.7	11.7	—	11.2
	——		—	17.3*	—	17.3*
2nd Preliminary Tremor.	**4.6**	0.24	4.5	—	**5.5**	4.9
	——		**9.6**	10.2	**7.9** / 10.1	9.7
	——		13.6	13.4	**12.8**	13.4
	——		16.2	—	14.5	15.4
	21.3	0.37	—	—	—	21.3
	26.9	0.34	—	—	—	26.9
	——		38.0	—	—	38.0
	——		47.5	—	—	47.5

Phase of motion.	Potsdam.		Leipzig.	Göttingen.	Upsala.	**Mean.**
	T sec.	2*a* mm	*T* sec.	*T* sec.	*T* sec.	*T* sec.
	4.0	—	—	—	—	4.0
	7.7	0.33	**9.3**	—	8.4	8.5
	——		—	—	15.9	15.9
1st and 2nd Ph.,	30.5	0.33	**29.7**	30.6	—	30.3
Princ. Portion.	——		**36.8**	36.0	—	36.4
	43.3	0.47	—	—	—	43.3
	——		49.2	48.3	—	48.8
	55.2	1.55	—	—	—	55.2
	——		**9.0**	**9.4**	**9.3**	9.2
	——		12.0	11.0	13.4	12.1
3rd, etc. Ph.,	16.2*	2.50	—	15.0*	—	15.6*
Princ. Portion.	19.6	1.00	20.9	—	—	20.3
	24.1	—	24.3	—	—	24.2
	29.5	1.28	—	—	—	29.5
	——		**10.2**	—	**9.2**	9.7
	——		—	—	**11.9**	11.9
End	——		—	17.6*	**14.3**	14.3 / 17.6*
Portion.	——		**22.4**	—	**21.9**	22.2
	——		—	—	26.6	26.6

A glance on Tables XXIV, XXX, XXXI, XXXII, XXXIII, and XXXIV, will show that several periods existed simultaneously at the different stations. To show this relation more clearly, I have collected in the following table the mean values of the different periods and the corresponding max. 2*a*'s occurring in the succes-

sive phases of the earthquake motion for the 16 stations considered before; similar periods being placed on the same horizontal rows.†

TABLE XXXV. Kangra Earthquake. Periods of Vibration and Max. $2a$ at the different Stations. [GENERAL SUMMARY.]

(*....Pendulum Oscillations.)

Phase of motion.	Tokyo.	Ōsaka; Kōbe; Tadotsu.	Taihoku; Taichu; Tainan.	Birm'gham; Quarto-Castello.	Potsdam; Leipzig; Göttingen; Upsala.	Chelt'ham; Wash'gton; Tacubaya.	**Mean Periods.**
	T $2a$ sec. mm	T $2a$ sec. mm	T $2a$ sec. mm	T $2a$ sec. mm	T sec.	T $2a$ sec. mm	T sec.
1st Preliminary Tremor.	4.5 0.25	4.6 0.53	4.3 0.17	4.5 0.04	4.6	4.3 —	**4.5**
	7.8 0.33	7.8 —	5.8 —	6.8 0.02 9.1 0.07	8.4	7.6 —	**8.1** 6.3
	——	11.0 —	——	12.0 0.04	11.2	——	11.4
	15.8 0.22	——	13.8 0.08	——	—	13.0 0.05	14.2
	20.0 0.43	——	——	——	17.3*	——	20.0 17.3*
	24.7 0.57	24.0 1.05	——	——	—	——	24.4
	29.8 0.43	——	——	——	—	30.3 —	30.1
	——	——	——	——	—	40.7 0.15	40.7
2nd Preliminary Tremor.	4.8 0.21	——	4.7 0.33	4.7 0.04	4.9	——	**4.8**
	9.0 1.06	——	——	9.2 0.26	9.7	8.4 —	**9.1**
	11.8 1.05	——	11.2 2.30	11.1 0.25	13.4	11.5 —	**11.4** 13.4
	——	14.8 —	——	15.5 0.08	15.4	14.4 0.05	**15.0**
	23.1 2.33	20.2 1.58	21.0 0.10	——	21.3	21.4 —	**21.0** 23.1
	26.5 0.97	25.5 1.69	——	——	26.9	24.6 0.06	**25.9**
	——	30.9 3.00	——	——	—	29.4 0.09	30.2
	33.5 1.63	——	——	——	—	32.2 0.10	32.9
	37.1 4.50	36.5 0.14	——	——	38.0	——	**37.2**
	40.4 3.53	——	——	——	—	40.3 0.10	40.4
	45.3 3.95	——	——	——	47.5	46.0 0.07	**46.3**
	49.7 5.80	——	——	——	—	——	49.7
	54.6 —	——	——	54.5 —	—	——	54.6
	86.0 2.27	——	——	——	—	——	86.0

† The $2a$ in Table XXXV is the greatest value, among the different stations, of the range of motion in EW or NS component, corresponding to a given period.

TABLE XXXV. *Cont.*

Phase of motion.	Tokyo.	Osaka; Kobe; Tadotsu.	Taihoku; Taichu; Tainan.	Birm'gham; Quarto-Castello.	Potsdam; Leipzig; Göttingen; Upsala.	Chelt'ham; Wash'gton; Tacubaya.	**Mean Periods.**
	T 2*a* sec. mm	*T* 2*a* sec. mm	*T* 2*a* sec. mm	*T* 2*a* sec. mm	*T* sec.	*T* 2*a* sec. mm	*T* sec.
	——	——	4.5 0.23	4.9 —	4 0	——	**4.5**
	8.7 0.40	——	6.8 0.50	7.5 —	8.5	——	**7.9**
	11.3 0.33	——	10.0 2.00	9.5 0.30	—	——	**10.3**
	16.8 0.53	——	15.9 —	——	15.9	14.7 —	**15.8**
1st and 2nd	22.3 0.13	20.4 —	——	18.8 0.16	—	——	**20.5**
Phases,	——	——	——	——	—	24.7 0.12	24.7
Principal	28.8 6.24	28.3 4.50	30.0 3.10	29.8 0.44	30.3	29.9 0.24	**29.5**
Portion.	37.7 0.58	34.0 0.48	——	36.6 0.24	36.4	37.5 0.12	**36.4**
	42.5 —	39.9 4.80	41.2 0.22	——	—	40.3 0.10	**41.0**
	46.5 6.65	——	——	——	43.3	45.2 0.12	**45.0**
	——	——	——	50.0 0.22	48.8	48.8 0.09	**49.2**
	53.0 10.80	55.8 2.00	——	——	55.2	55.7 0.12	**54.9**
	59.0 1.30	——	——	——	—	——	59.0
	——	——	——	——	—	63.2 0.14	63.2
	——	——	5.4 0.33	6.9 0.03	—	——	6.2
	10.4 3.67	11.3 —	9.9 12.80	10.0 0.44	9.2 12.1	——	**10.2** 12.1
	15.5 2.40	18.5 2.00	14.6 11.90	16.5 1.56	15.6*	15.1 —	**15.5** 18.5
3rd Phase,	22.1 —	——	——	——	20.3	21.9 0.12	**21.4**
Principal	——	24.2 2.25 27.7 11.70	——	26.6 0.72	24.2	24.0 0.12	**24.8** 27.7
Portion.	——	32.0 2.70	——	31.4 2.30	29.5	——	**31.0**
	34.8 Large	——	——	——	—	——	34.8
	42.5 2.70	——	——	——	—	——	42.5
	——	——	5.9 0.17	4.9 —	—	——	5.4
	8.2 0.24	10.5 0.53	8.4 1.20	9.6 0.38	9.7	——	**9.3**
4th, etc. Ph.,	11.2 2.20	——	10.3 0.50	——	11.9	——	**11.1**
Principal	12 7 1.67	——	12.7*6.80	12.2 0.60	—	——	**12.5**
Portion.;	15.5 0.78	13.7 0.63	——	14.5 0.57 16.7 0.22	14.3	15.6 0.21	**14.7** 16.7
End Portion.	19.5 1.30	18.7 0.72	——	18.8 0.48	17.6*	——	**18.7**
	22.6 0.58	22.8 1.73	22.3 —	——	22.2	21.6 0.05	**22.3**
	26.2 —	——	——	——	26.6	——	26.4

The values of the different periods occurring in the Kangra earthquake (Table XXXV), obtained by taking the averages from the various phases of the earthquake motion are indicated in Table XXXVI. For the sake of comparison, I have also given in the same table the periods which were found for the following three sets of great teleseismic disturbances :—

(i) Tokyo Horizontal Components Observation of the Caracas earthquake of Oct. 29, 1900, and the Guatemala earthquake of April 19, 1902.

(ii) Tokyo, Ōsaka, and Manila Observations of the Valparaiso earthquake of Aug. 17, 1906. Horizontal and Vertical Components.

(iii) E W Component Observations in Tokyo of the 10 earthquakes, namely, 3 Alaska eqkes of Sept. 4 and 10, 1899, and Oct. 9, 1900; 2 Mexico eqkes of Jan. 20, 1900, and Sept. 22, 1902; Guatemala eqke of April 19, 1902; Caracas eqke of Oct. 29, 1900; Aidin eqke of Sept. 20, 1899; Kashgar eqke of Aug. 22, 1902; and Sumatra eqke of Jan. 5, 1900.

These 10 earthquakes, together with the Guam Island eqke of Sept. 22, 1902, compose the 11 disturbances referred to in § 8. The two earthquakes of Group (i) are included in Group (iii).

TABLE XXXVI. Periods of Vibration in Kangra, Valparaiso, and other Earthquakes.

i	ii	iii	iv	Mean Values of Periods, deduced from (ii), (iii), (iv).	
Caracas and Guatemala Earthquakes (Tokyo, Horiz.)	Valparaiso Earthquake (Tokyo, Ōsaka, Manila).	10 Large Eqkes observed in Tokyo (EW Component).	Indian Eqke* (16 Stations).		
sec.	sec.	sec.	sec.	sec.	
—	—	1.5	—		
2.9	—	—	—		
—	4.0	4.1	**4.7**	**4.3**	P_1
7.9	8.4	**8.9**	**8.6**	**8.6**	P_2
10.2	11.4	—	**11.2**	**11.3**	$P_{2,3}$
14.8	15.1	**14.5**	**15.1**	**14.9**	P_3
18.4	18.3	—	—	**18.3**	P_4
—	—	**20.0**	**20.7**	**20.4**	P_5
21.2	22.6	—	—	**22.6**	$P_{5,6}$
26.9	26.8	24.6	**25.6**	**25.7**	P_6
—	28.7	28.3	—	**2.58**	P_7
—	—	—	**30.1**	**30.1**	$P_{7,8}$
32.9	32.4	—	—	**32.4**	P_8
—	37.1	**34.4**	**36.4**	**35.9**	P_9
39.5	—	42.9	**41.1**	**42.0**	P_{10}
45.4	45.0	—	45.7	**45.4**	P_{11}
—	—	—	49.4	**49.4**	P_{12}
56.0	—	54.0	54.8	**54.4**	P_{13}
—	—	—	59.0	**59.0**	P_{14}
—	67.4	66.0	63.0	**65.5**	P_{15}
			⋮	⋮	⋮
—	—	—	86.0	**86.0**	P_{19}

(*The quick vibrations which occurred in some of the diagrams of the Kangra earthquake are noted in a subsequent §.)

From Table XXXVI, it will be seen that many periods of vibration are common to the four groups (i) to (iv). Especially the periods in the Caracas and Guatemala earthquakes observed in Tokyo were very nearly alike to those in the Valparaiso earthquake observed in Tokyo, Ōsaka, and Manila; while the periods occurring in the Kangra earthquake were similar to those found in the cases of the 10 earthquakes of group (iii). We are, therefore, justified in deducing the average values of the various periods from observations of the different earthquakes. The results thus obtained from (ii), (iii), and (iv),* are denoted in the table by the symbols P_1, P_2.....P_{15}.....P_{19}. Of these, the periods (P_1 to P_{11}) and P_{13} correspond respectively to the successive periods represented by the same letters in § 8. The periods P_{12}, P_{14}, P_{15}, and P_{19} form additions to the series before obtained.

As stated in my previous papers,† we have the following approximate relations:—

$$P_1=\frac{P_2}{2}=\frac{P_3}{3}=\frac{P_4}{4}=\ldots\ldots\frac{P_{10}}{10}=\ldots\ldots\frac{P_n}{n},$$

where n denotes an integer, whose maximum limit is provisionally 19. According to the above assumption, P_1 is to be regarded as the fundamental or unit period of the micro-seismic movements, the different longer periods being its multiples. The most probable value of P_1 may be found as follows:—

$$P_1=\sum_1^{15}P_n\Big/\sum_1^{15}n=\mathbf{4.2}\text{ sec.},$$

$P_{19}=86$ sec. being, for the present calculation, left out of account, as it depends on a single observation. (Compare the *Publications*, No. 21, p.p. 83–84.)

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* (i) is included in (iii).

† The *Publications*, No. 21.

The conclusion to be drawn, with respect to the vibration periods, from what has been said above is as follows:—The teleseismic motion is essentially the same in character at different places all over the world, and consists of a set of vibrations, whose periods are approximately equal to P_1, P_2, P_3..... These latter may be considered as the seismic constants, not of a particular district, but of the whole earth's crust. Short period vibrations, which constitute the macro-seismic or sensible earthquake motion, are of short wave length and much depend on the nature of the ground of the observing place.

The discussions in these §§ are to be regarded only as provisionary; the division of the periods of vibration into the different groups, P_1, P_2, P_3,..... being sometimes more or less arbitrary. Besides the 16 mean periods considered above there are two frequently occurring intermediate ones, respectively equal to 11.3 and 22.6 sec., and denoted in Table XXXVI by $P_{2,3}$ and $P_{5,6}$. The lengths of these two periods are in the ratio of 1 : 2. In the Kangra earthquake there was also a third intermediate period of $P_{7,8}=30.1$ sec.

131. ***Periods of Micro-seismic Vibrations in the different Phases.*** According to Table XXXV, the periods of the micro-seismic vibrations occurring in the successive phases of the Kangra earthquake were as follows, those more frequently occurring being, as usual, printed in fat characters:—

TABLE XXXVII. Kangra Earthquake. Periods of Vibration occurring in the Successive Phases of the Earthquake Motion.

1st Preliminary Tremor.	2nd Preliminary Tremor.	1st and 2nd Ph., Princ. Portion.	3rd Phase, Principal Portion.	4th and 5th Ph., Princ. Portion; End Portion
P_1	P_1	P_1	P_1	P_1
P_2	P_2	P_2	—	P_2
$P_{2,3}$	$P_{2,3}$	$P_{2,3}$	$P_{2,3}$	$P_{2,3}$
P_3	P_3	P_3	P_3	P_3
—	—	—	—	P_4
P_5	P_5	P_5	P_5	—
—	—	—	—	$P_{5,6}$
P_6	P_6	P_6	P_6	P_6
—	—	—	P_7	
$P_{7,8}$	$P_{7,8}$	$P_{7,8}$	$P_{7,8}$	
—	P_8	—	—	
—	P_9	P_9	P_9	
P_{10}	P_{10}	P_{10}	P_{10}	
	P_{11}	P_{11}		
	P_{12}	P_{12}		
	P_{13}	P_{13}		
	—	P_{14}		
	—	P_{15}		
	⋮			
	P_{19}			

(*i*) According to the above table, the longest period P_{19} occurred in the 2nd preliminary tremor, while the two next longest ones, P_{15} and P_{14}, occurred only in the 1st and 2nd phases of the principal portion. Again the three next longest periods, P_{13}, P_{12},

and P_{11}, occurred only in the three above-named sections. On the whole the periods characterizing the 2nd preliminary tremor seem to be identical with those characterizing the 1st and 2nd phases of the principal portion, with the difference that similar periods did not have the same amplitudes in these different sections of motion, as follows :—

(i) In the 2nd preliminary tremor, the periods of the predominating larger vibrations were P_5 to P_{12};

(ii) In the 1st and 2nd phases of the principal portion, the vibrations of the periods P_1 to P_6 were small, those of the periods P_7 to P_{13} being much larger than the rest. The vibrations of P_2 and $P_{2,3}$ were here much smaller than in the preceding section.

(*ii*) With respect to the 1st preliminary tremor and the 3rd phase of the principal portion, we see that the periods occurring in these two sections are nearly alike; the longest period being P_{10} in each case. The principal differences between the two sections in question were as follows :—

(i) All the vibrations, with the exception of that of the period P_1, are much greater in the 3rd phase of the principal portion than in the 1st preliminary tremor.

(ii) The predominating vibrations in the 1st preliminary tremor are those of the periods P_1 to P_3.

(iii) The most active vibrations in the 3rd phase of the principal portion are those of the periods $P_{2,3}$ to P_8.

(*iii*) In the 4th and 5th phases of the principal portion and in the tail, or end portion, the predominating periods were P_2 to $P_{5,6}$.

The periods occurring throughout the successive phases of the earthquake motion were P_1 to P_6.

132. ***Range of Motion*** **(2*a*)** ***corresponding to the different Periods, P's.*** The following table, giving the ranges of motion, 2*a*'s, corresponding to the different periods *P*'s, has been formed from the data contained in Table XXXV, and relates to the 12 places of Tokyo, Ōsaka, Kōbe, Tadotsu, Taihoku, Taichu, Tainan, Birmingham, Quarto-Castello, Cheltenham, Washington, and Tacubaya.

In Table XXXVIII the "mean 2*a*" is the average value of the max. 2*a*'s in one or the other of the two horizontal components at the different stations, corresponding to a given period; the "greatest 2*a*" being the absolutely largest among these max. 2*a*'s. The max. 2*a*'s evidently due to the proper pendulum oscillation, which are marked each with an *asterisk*(*), have been excluded in the deduction of the mean 2*a*'s.

TABLE XXXVIII. Kangra Earthquake.
2*a* corresponding to the different *P*'s.

Period.	Greatest 2*a*.	Mean 2*a*
	mm	mm
P_1	0.53	0·23
P_2	1.20	0.47
$P_{2,3}$	12.90* (next greatest, 3.67)	1.28
P_3	11.90* („ „ , 2.40)	0.60
P_4	2.00	0.84
P_5	1.58	0.85
$P_{5,6}$	2.33	0.96
P_6	2.25	0.84
P_7	11.70* (next greatest, 6.24)	4.48
$P_{7,8}$	3.10	1.22

Period.	Greatest $2a$.	Mean $2a$.
	mm	mm
P_8	2.70	1.68
P_9	4.50	1.01
P_{10}	4.80	1.66
P_{11}	6.65	2.70
P_{12}	5.80	2.04
P_{13}	10.80* (next greatest, 2.00)	1.06
P_{14}	1.30	1.30
P_{15}	0.14	0.14
⋮	⋮	⋮
P_{19}	2.27	2.27

From Table XXXVIII it will be seen that the mean $2a$'s corresponding to the 4 periods, P_1, P_2, P_3, and P_4, are roughly in the ratios of 1 : 2 : 3 : 4, showing an increase of the amplitude with the period. The $2a$'s for P_4, P_5, $P_{5,6}$, and P_6 were nearly constant, varying only between 0.84 and 0.96 mm. The amplitude seems to reach its greatest value approximately for P_{11}, as is graphically illustrated in Fig. 19. The curve, drawn with free hand through the mean positions between the different dots (•), passes through the origin of co-ördinates, which agrees with the fact that quick vibrations of macroseismic nature are very slight in the teleseismic motion. The relation between the different periods, P_1, P_2, ..., and the corresponding *greatest* $2a$'s, illustrated in Fig. 18, presents the same general character as in the case considered above.

The results thus far arrived at respecting the dependence of the amplitude on the period may be summarized as follows :—

In the teleseismic motion, the $2a$ increases with the period, from nearly zero to a maximum (absolute maximum in a single horizontal component=6.65 mm) for the period P_{II}=45.4 sec.

133. ***The Order of Occurrence of the different Periods in the Principal Portion of the Earthquake Motion.*** The horizontal pendulum observation of earthquakes, made in Tokyo between 1898 and 1904, has shown that, in the teleseismic motion due to a great source of disturbance, the different periods of vibration in the *principal portion* generally tend to occur in a descending order, that is to say, the vibrations at the commencement of the 1st phase (3rd section) has the longest period, those in the subsequent phases having periods of successively decreasing length.* The observation of the Kangra earthquake at the different stations also indicates the same fact, as is shown in the 3rd column of Table XXXIX, in which the periods in the 1st to 5th phases of the principal portion (3rd to 7th sections) are given in terms of the P's in the order of their occurrence. This peculiar characteristic of the earthquake motion is to be most clearly ascertained with seismographs whose "steady mass" has a long oscillation period.

* See the *Publications*, No. 21, p.p. 84-86.

Indian Earthquake of 1905.

Relation between the Period and Amplitude.

Fig. 18.....$2a$ = Absolutely greatest max. motion.

Fig. 19.....$2a$ = mean value of max. $2a$'s.

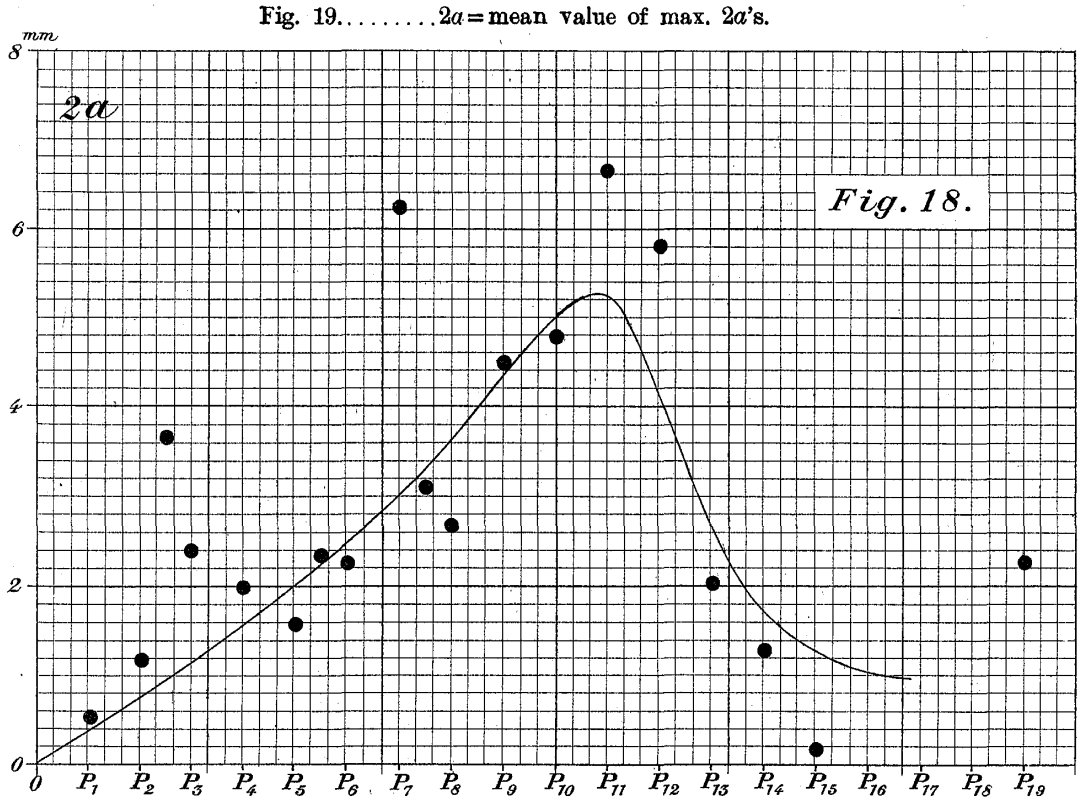

Fig. 18.

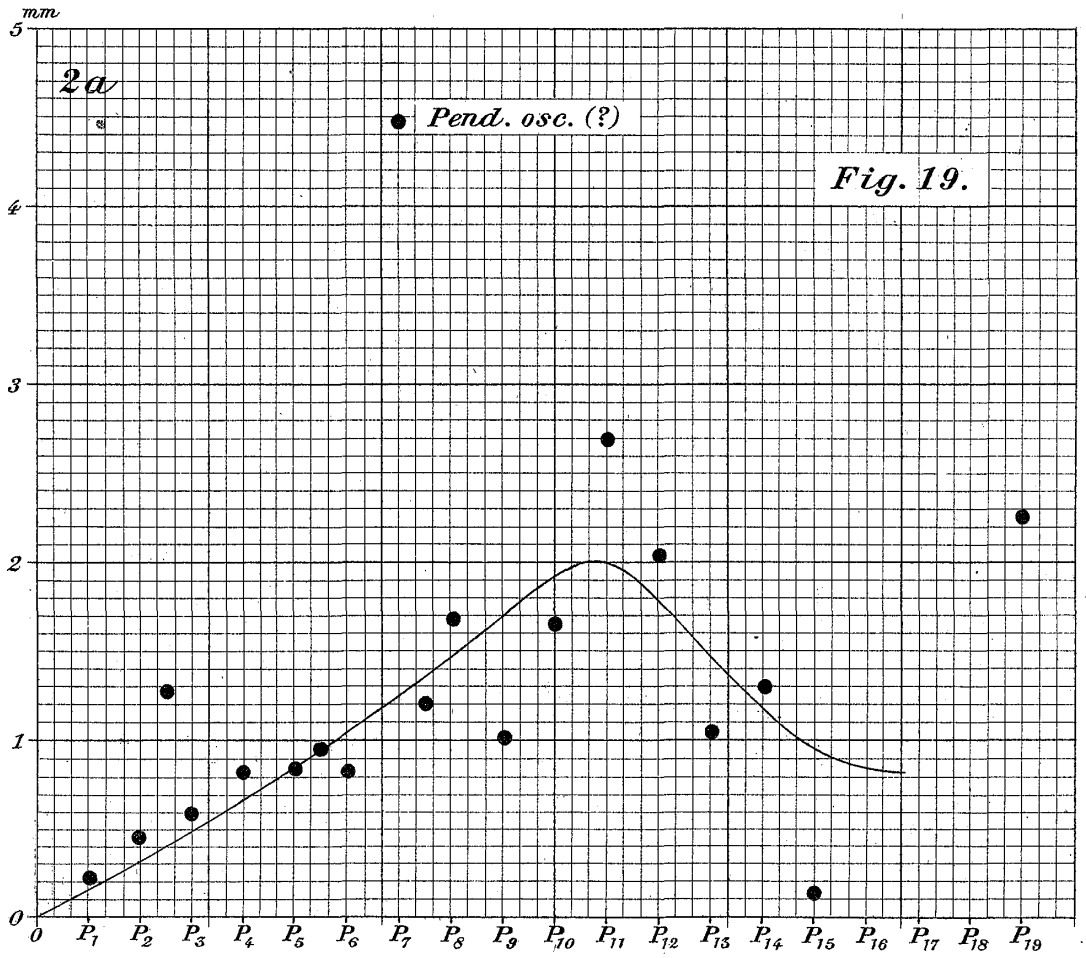

Fig. 19.

TABLE XXXIX. Kangra Earthquake. The Order of Occurrence of the different Periods in the 2nd Preliminary Tremor and in the Principal Portion of the Earthquake Motion.*

Station.	2nd Preliminary Tremor.	1st to 5th Phases, Principal Portion.
Tokyo (EW)	$P_9\ P_{12}\ P_{13}\ P_{19}\ \begin{cases} P_6 \\ P_2 \end{cases}$	$\begin{cases} P_{14} \\ P_{2,3} \end{cases}\ P_{13}\ P_7\ P_4\ \begin{cases} P_{2,3} \\ P_5 \end{cases}\ P_{2,3}\ P_{2,3}\ P_{2,3}$
,, (NS)	$\begin{cases} P_{11} \\ P_{5,6} \end{cases}\ \begin{cases} P_8 \\ P_{13} \end{cases}\ \begin{cases} P_{11} \\ P_{10} \end{cases}$	$P_{10}\ P_{12}\ P_{10}\ \begin{cases} P_{2,3} \\ P_{5,6} \end{cases}\ P_{2,3}\ \begin{cases} P_5 \\ P_{2,3} \end{cases}\ P_{2,3}\ P_{5,6}$
,, (Vertical)	.....	$P_{11}\ P_{7,8}\ P_{5,6}\ P_3\ P_3$
Ōsaka (EW)	$P_{2,3}\ P_8\ P_6\ P_{7,8}$	$P_{5,6}\ P_7\ P_6\ \begin{cases} P_6 \\ P_{2,3} \end{cases}\ \begin{cases} P_{5,6} \\ P_{2,3} \end{cases}\ \begin{cases} P_4 \\ P_3 \\ P_{2,3} \end{cases}$
Kōbe (NS)	.....	$P_9\ P_{13}\ P_{10}\ P_7\ \begin{cases} P_8 \\ P_5 \end{cases}\ \begin{cases} P_{5,6} \\ P_2 \end{cases}\ \begin{cases} P_4 \\ P_{2,3} \end{cases}$
Tadotsu (EW)	.....	$\begin{cases} P_{10} \\ P_4 \end{cases}\ P_7\ \begin{cases} P_5 \\ P_{2,3} \end{cases}\ P_{2,3}$
Taihoku (EW)	.....	$\begin{cases} P_{10} \\ P_{2,3} \\ P_1 \end{cases}\ P_{7,8}\ P_3\ \begin{cases} P_{2,3} \\ P_1 \end{cases}$
Washington (NS)	.....	$P_{11}\ P_{12}\ P_7\ P_5\ P_3$
Cheltenham (EW)	.....	$P_{15}\ \begin{cases} P_{13} \\ P_3 \end{cases}\ \begin{cases} P_{11} \\ P_{5,6} \end{cases}\ \begin{cases} P_{7,8} \\ P_3 \end{cases}\ P_5\ \begin{cases} P_5 \\ P_3 \end{cases}\ P_3$
,, (NS)	$\begin{cases} P_{7,8} \\ P_2 \end{cases}\ P_{2,3}\ P_{11}\ P_6$	$\begin{cases} P_{15} \\ P_6 \end{cases}\ \begin{cases} P_{12} \\ P_3 \end{cases}\ P_{7,8}\ P_4\ P_5\ P_3\ P_3$
Tacubaya (EW)	.....	$P_{14}\ P_{11}\ P_9\ P_6\ P_{5,6}\ P_4\ \begin{cases} P_3 \\ P_4 \\ P_5 \end{cases}$

*The different periods occurring simultaneously in one and the same epoch are indicated by a bracket.

Station.	2nd Preliminary Tremor.	1st to 5th Phases, Principal Portion.
Tacubaya (NS)	.....	P_{11} P_{10} P_6 P_5 P_3 P_3
Potsdam (EW)	.....	$\begin{Bmatrix} P_5 \\ P_1 \end{Bmatrix}$ P_{11} $\begin{Bmatrix} P_{7,8} \\ P_2 \\ P_1 \end{Bmatrix}$ $P_{7,8}$ P_5 P_3 $\begin{Bmatrix} P_3 \\ P_5 \end{Bmatrix}$
Göttingen (NS)	.....	P_{12} P_9 $P_{7,8}$ $\begin{Bmatrix} P_3 \\ P_{2,3} \end{Bmatrix}$ $\begin{Bmatrix} P_3 \\ P_2 \end{Bmatrix}$ $\begin{Bmatrix} P_3 \\ P_2 \end{Bmatrix}$

Thus it will be seen that in the majority of cases, the series began with slow vibrations of periods, P_{11} to P_{15}, thence becoming successively quicker towards the end of the principal portion. Especially, at Tokyo (EW, NS, and Vertical), Tadotsu (EW), Taihoku (EW), Cheltenham (EW and NS), Tacubaya (EW and NS), and Göttingen (NS), the succession of the different periods was in a perfect decreasing order.

It is here to be noted that what was said above respecting the order of occurrence relates only to the predominating vibrations in the principal portion, some of the small vibrations with shorter periods occurring more or less in the different sections of the earthquake motion.

134. ***Periods Occurring in the 2nd Preliminary Tremor.*** The vibrations in the 2nd preliminary tremor do not generally indicate a definite order of occurrence according to the lengths of their periods. There seems, however, to exist a tendency for an increasing order of periods, as shown, for a few places, in the 2nd column of Table XXXIX.