the maximum at an epicentral distance of $x=50°$ to $60°$, as illustrated in Fig. 15, Pl. VIII; the greatest values of the v_1 and v_2 being 10.03 and 5.62 km/sec. The greatest values of the two velocities calculated by "direct method" on the supposition of the *arcual* transmission are 10.79 and 6.23 km/sec., respectively.

The existence of the maximum in the value of each of the two velocities v_1 and v_2 calculated by the "direct method" seems to indicate the absurdity of the supposition of the chord transmission of the vibrations composing the 1st and 2nd preliminary tremors of the teleseismic motion.

Chapter VII. Duration of the 1st Preliminary Tremor.

119. ***Observations at the Different Stations.*** The duration (y_1) of the 1st preliminary tremor for each of the 37 different stations or group of stations is given in Table XIX, the longest value being $17^m\ 10^s$ for Apia and Tacubaya, whose mean x is 121° 58′.

TABLE XIX. Duration of the 1st Preliminary Tremor.

Station.	Epicentral Distance $=x$.	Duration of 1st Prel'nary Tremor $=y_1$.
Taschkent.	11° 20′	$2^m\ 05^s$
Colaba (Bombay).	13 28	3 31
Calcutta.	13 42	3 09
Mean	**13 35**	**3 20**

Station.	Epicentral Distance $=x$.		Duration of 1st Prel'nary Tremor $=y_1$.	
Kodaikanal.	21°	35′	3^m	55^s
Tiflis.	27	26	4	43
5 Caucasian Stations.*	27	11	4	41
Mean.....	**26**	**10**	**4**	**33**
Taichu.	39	051	6	14
Tainan.	39	06	6	15
Taihoku.	39	27	6	06
Batavia.	42	35	7	00
Manila.	43	34	6	38
Mean.....	**40**	**45**	**6**	**27**
Tadotsu.	47	02	7	00
Upsala.	47	41	6	57
Kōbe.	48	03	7	00
Ōsaka.	48	19	7	12
Laibach.	49	19	7	17
Messina.	49	46	7	15
Potsdam.	49	48	7	05
Triest.	49	52	7	00
Pola.	49	55	7	14
Leipzig.	50	16	7	09
Ischia.	50	30	7	18
Rocca di papa.	51	15	7	18
Tokyo.	51	26	7	17
Mizusawa.	51	39	7	20
Göttingen.	51	45	7	17
Querce.	51	54	7	16
Ximeniano.	51	55	7	14

* Achalkalaki, Batum, Borshom, Derbent, Schemacha.

Station.	Epicentral Distance $=x$.		Duration of 1st Prel'nary Tremor $=y_1$.	
Quarto Castello.	51°	56′	7^m	15^s
Mean.....	**50**	**12**	**7**	**11**
Mauritius.	55	15	8	09
Birmingham.	58	49	8	21
Paisley.	59	30	8	18
Mean.....	**57**	**51**	**8**	**16**
Cape Town.	85	46	9	57 (?)
Cheltenham.	105	22	14	44
Washington, D.C.	105	17	15	12
Mean.....	**105**	**20**	**14**	**58**
Apia (Samoa).	115	08	17	42
Tacubaya.	128	47	16	38
Mean.....	**121**	**58**	**17**	**10**

Comparing the observations at the Japanese stations with those at the Middle Europe stations, we obtain the following results :—

(i) *Japan* :—Tadotsu, Kōbe, Ōsaka, Tokyo, Mizusawa.....
Mean $x=49°\,39'$, $y_1=7^m\,11^s$.

Middle Europe :—Upsala, Laibach, Messina, Potsdam, Triest, Pola, Leipzig, Ischia, Rocca di papa, Göttingen, Querce, Ximeniano, Quarto-Castello.....
Mean $x=50°\,27'$, $y_1=7^m\,12^s$.

Again, taking only those stations, whose epicentral distance is about $51°\frac{1}{2}$, we obtain the following results :—

(ii) { *Japan*:—Tokyo, Mizusawa..... *Mean* $x=51°\,30'$, $y_1=7^m\,18^s$.
Middle Europe: Leipzig, Ischia, Rocca di papa, Göttingen, Querce, Ximeniano, Quarto-Castello.....
Mean $x=51°\,22'$, $y_1=7^m\,15^s$.

According to (i), the duration y_1 was the same for the Japanese stations and those of Middle Europe, the mean distance for the former group being nearly $50'$ greater than for the latter. But according to (ii), the mean values of y_1 and x for the two Japanese stations of Tokyo and Mizusawa were very nearly the same as those for 7 German and Italian stations. From this it may be conjectured that the relation between x and y_1 depends only slightly on the nature of the path of the earthquake propagation.

120. ***Relation between the Epicentral Distance and the Duration of the 1st Preliminary Tremor.*** According to Table XIX, the mean group values of the epicentral distance (x) and the corresponding duration (y_1) of the 1st preliminary tremor are as follows:—

(i)	$x=11°\,20'$....	$y_1=2^m\,05^s$	(1 station)
(ii)	13 35	3 20	(2 stations)
(iii)	26 10....	4 33	(7 „)
(iv)	40 45	6 27	(5 „)
(v)	50 12	7 11	(18 „)
(vi)	57 51	8 16	(3 „)
(vii)	105 20	14 58	(2 „)
(viii)	121 58	17 10	(2 „)

The variation of y_1 with x is illustrated in Fig. 16, from which it will be seen that the relation between the two quantities, for the group values of (iii) to (viii), may approximately be represented by a straight line. Assuming, therefore, a linear equation between x and y_1 for the limits under consideration, and calculating by

Method of Least Squares the values of the constants, we obtain :—

$$(1) \ldots\ldots\ldots x^{km} = 13.77\ y_1^{sec.} - 576^{km}$$

The above equation, which is to be regarded as applicable for x between about 20° and 120°, refers to the observations at different stations of the Kangra Eathquake, and differs from the formulae given in the *Publications*, Nos. 5 and 13, which related to different earthquakes observed in Tokyo.

121. ***Comparison with the Turkestan and San Francisco Earthquakes.*** Comparing the relations between the x and y_1 obtained for the Indian earthquake with those obtained for the Turkestan (Kashgar) earthquake of 1902 and the San Francisco earthquake of 1906, we have :—

(1) Indian Earthquake $\ldots\ldots x^{km} = 13.77\ y_1^{sec.} - 576^{km}$
(2) Turkestan „ *$\ldots\ldots x = 11.80\ y_1 - 60$
(3) San Francisco „ †$\ldots\ldots x = 16.79\ y_1 - 1618$

The equations (2) and (3) were obtained from the observations at different seismological stations, relating respectively to the Turkestan and San Francisco earthquakes. It thus seems that the relation between the x and y_1 is not the same for different earthquakes. Of the above three equations, (2) is to be taken as of less value than the two others, being based on a less number of observations. Supposing the weight of the two equations (1) and (3) to be double that of (2), and taking the averages I obtain the following provisional result :—

$$(4) \ldots\ldots\ldots x^{km} = 14.58\ y_1^{sec} - 890^{km}$$

which is to be regarded as holding good for x between about 20° and 140°.

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* See the *Bulletin*, Vol. I, No. 4.
† „ „ „ , Vol. I, No. 1.

122. ***Comparison with Earthquakes of Near Origin.*** According to the results of the observations in Tokyo of the large teleseismic disturbances mentioned in § 8, the durations of the 1st and 2nd preliminary tremors are in the ratio of 100 to 95. Hence if y denote the total duration of the 1st and 2nd preliminary tremors, Equation (4) of the preceding § is transformed into the following :—

$$(5)\ldots\ldots\ldots x^{km}=7.06\,y^{sec.}-576^{km},$$
$$\text{for}\quad 2000^{km}<x<\text{about}\ 16{,}000^{km}$$

Now, for the earthquakes of near origins observed in Tokyo, whose distance varied between 70 and 900 km, the relation between the epicentral distance (x) and the total duration (y) of the preliminary tremors were as follows*:—

$$(6)\ldots\ldots\ldots x^{km}=7.27\,y^{sec.}+38^{km},$$
$$\text{for}\quad 70^{km}<x<900^{km}$$

Thus we see that the rate of increase of the epicentral distance for 1 second of the duration of the preliminary tremor is practically the same for distant and near earthquakes, as follows :

$$\begin{cases}\text{Distant Eqs}\ldots\ldots\dfrac{dx}{dy}=7.06\text{ km}\\ \text{Near Eqs}\ldots\ldots\ldots\ \text{„}\ =7.27\ \text{„}\end{cases}$$

This fact probably indicates that the *rate* of separation with increase of the epicentral distance of the successive phases of the seismic motion is nearly the same for earthquakes of near and distant origins, within the limits of x under consideration.

The cases of those earthquakes, whose epicentral distance (x) is less than 70 or 100 km, must be treated specially.

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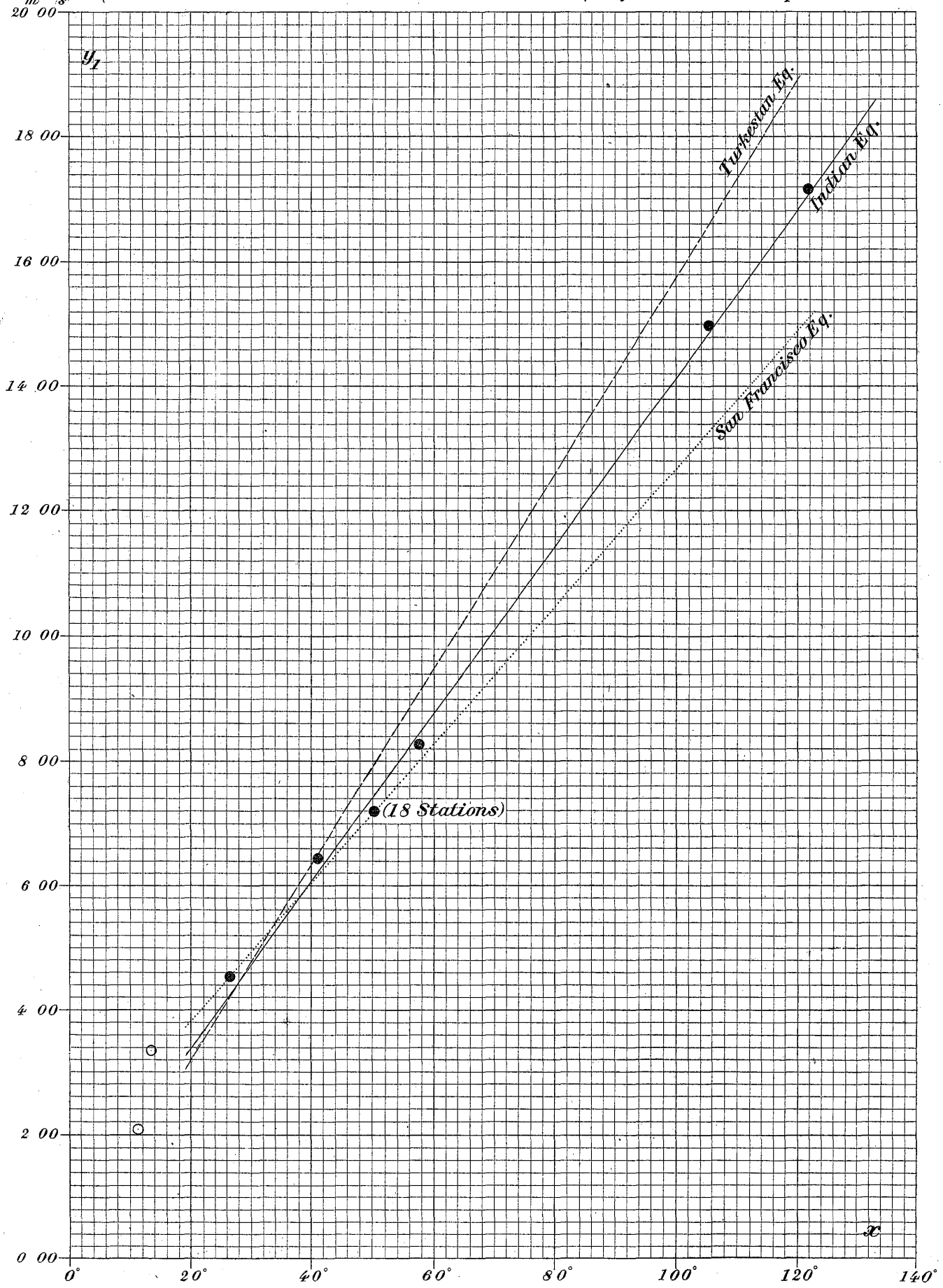
* The *Publications*, No. 13.

Fig. 16. Relation of the Duration of the 1st Preliminary Tremor to the Epicentral Distance.

The black dots (●) refer to Indian Eqke; 2 small white circles, which also refer to the same eqke (for Taschkent and 2 Indian Stations of Colaba and Calcutta) may relate to the total prel. tremor.



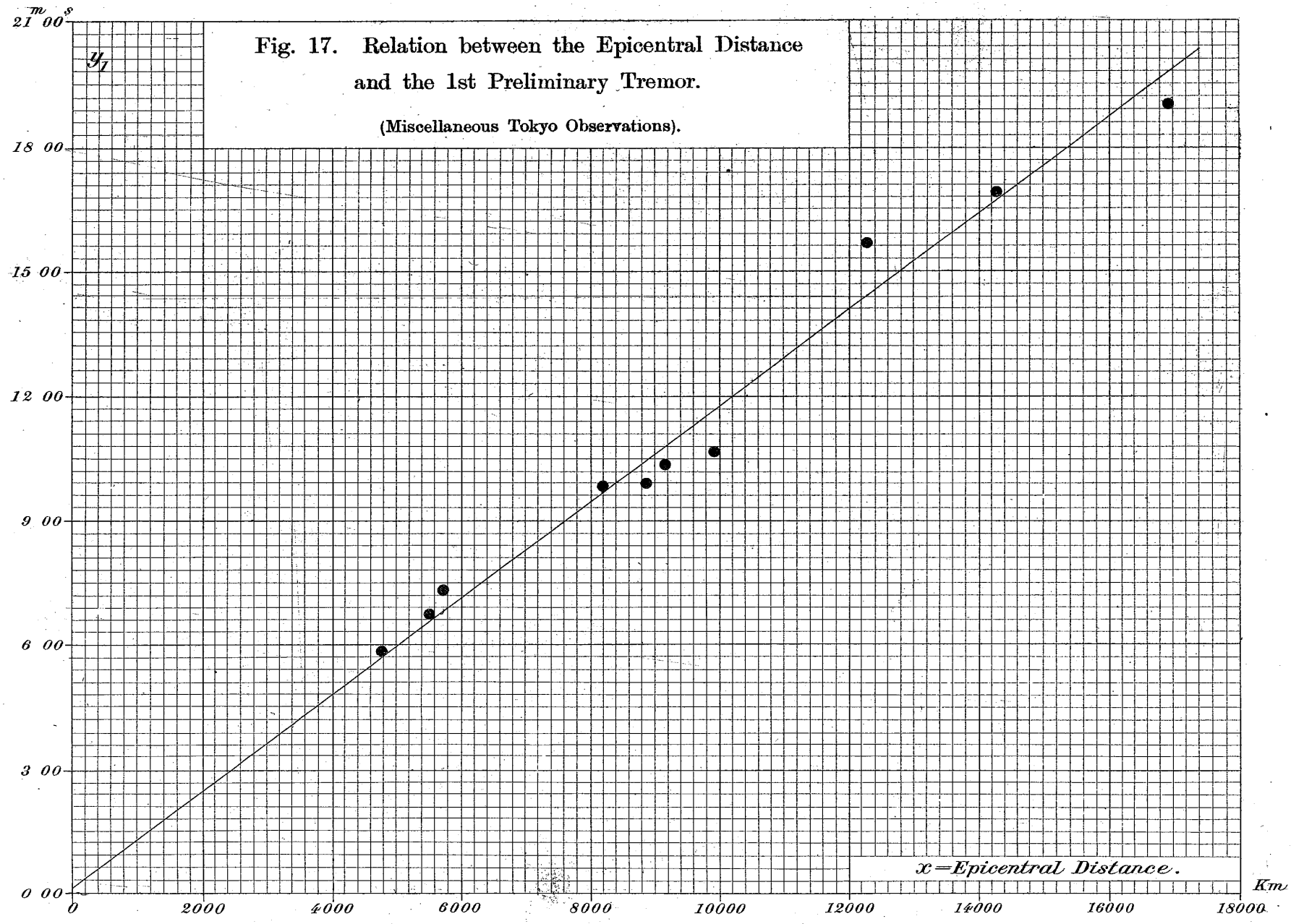


Fig. 17. Relation between the Epicentral Distance and the 1st Preliminary Tremor.
(Miscellaneous Tokyo Observations).
y_1
m s
21 00
18 00
15 00
12 00
9 00
6 00
3 00
0 00
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
Km
x=Epicentral Distance.

123. ***Relation between x and y_1 based on the Tokyo Observations of different Teleseismic Disturbances.*** Let us finally consider, for the sake of reference, the relation between the duration (y_1) of the 1st preliminary tremor and the epicentral distance (x), based on the horizontal pendulum observations at Tokyo of the following 10 large teleseismic disturbances, whose origins are more or less definitely known.

TABLE XX. Miscellaneous Observations in Tokyo.

Earthquake.	Date.	Time of Occurrence in Tokyo $=t_1$ (G.M.T.)	Position of Eqke Origin.		Epicentral Distance $=x$	Duration of 1st Prel. Tremor $=y_1$.
			Latitude.	Longitude.		
Ceram.	Sept. 29, 1899.	h m s 17 11 00	6° 00′ S	129° 00′ E	42° 56′	m s 5 46
Turkestan.	Aug. 22, 1902.	3 09 33	39 42 N	76 00 E	49 32	6 44
India.	April. 4, 1905.	0 59 08	31 49 N	77 00 E	51 26	7 17
San Francisco.	April. 18, 1906.	13 24 35	38 15 N	123 00 W	73 41	9 49
North Japan.*	Feb. 19, 1897.	21 01 05	38 30 N	143 30 E	79 26	9 55
Calabria.	Sept. 8, 1905.	1 56 09	38 50 N	16 16 E	89 02	10 41
Aidin.	Sept. 20, 1899.	2 24 27	37 50 N	29 00 E	82 29	10 19
Guatemala.	April. 19, 1902.	2 38 47	14 30 N	91 15 W	110 23	15 40
Caracas.	Oct. 29, 1900.	9 31 52	10 00 N	68 00 W	127 19	15 55
Valparaiso.	Aug. 17, 1906.	1 00 34	31 00 S	73 00 W	152 22	18 59

The relation between the t_1 and x is, as is graphically shown in Fig. 17, very irregular, due probably to some variation in the values of the constants characterizing the linear equation for each of the different earthquakes. Calculating the constants by Method of Least Squares from the results of the observations contained in the above table we obtain :—

* This earthquake was observed at Potsdam by the present author with Rebeur Horizontal Pendulum, the time (t_1), and the duration (y_1) of the 1st preliminary tremor are the values relating to Potsdam.

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

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.)