that the time (t_1) increased almost linearly with the distance (x) between about 30° and 120° (maximum limit).

Taking from Table IX, the mean group values of the epicentral distance and the corresponding time of occurrence of the 1st preliminary tremor, and calculating by the method of Least Squares, we find for the limits of x between 27° 57′ and 121° 16′,

$$v_1 = \mathbf{11.36} \text{ km per sec.}$$

Chapter V. Velocity of Propagation of the 2nd Preliminary Tremor.

102. ***Time of Commencement*** (t_2) ***and Transit Velocity*** (v_2) ***at Different Stations.*** The following table gives the epicentral distance (x) and the time of commencement (t_2) of the 2nd preliminary tremor for the 42 stations, whose seismograms indicated the last mentioned phase of motion with clearness; the different stations being divided, according to the epicentral distance, into a number of groups. The velocity v_2 given in the 4th column of the table has been calculated by "direct method" according to the formula

$$v_2 = \frac{x}{t_2 - t_0};$$

t_0 being the time of earthquake occurrence at the origin, assumed to be $0^h\ 49^m\ 48^s$ (G.M.T.).

Again, as will be seen from the results of the calculation of the velocity v_2 by "difference method" the times t_2 for Kodaikanal, Taungoo, and Batavia, seem to be a little too late. Accordingly these 3 stations (marked with *asterisks* in the Table) have been

excluded in deducing the mean values of the velocity v_2; the weight of the observations at those places, where the seismograms were apparently not quite satisfactory, being taken to be half that of the observations at the remaining places.

Table XI. Time of Commencement and Transit Velocity of the 2nd Preliminary Tremor.

Station.	Epicentral Distance $=x$.	Time of commencement of 2nd P. T. $=t_2$.	v_2 Calculated by "Direct Method."
		h m s	Km/sec.
Eqke Origin.	—	**0 49 48**	—
Dehra Dun.	1° 45′	0 50 38	—
Taschkent.	11 20	0 54 26	4.52
Colaba (Bombay).	13 28	0 56 39	3.64
Barrackpur.	13 32	0 55 41	4.26
Calcutta.	13 42	0 55 09	4.74
Mean.	**13 34**	**0 55 50**	**4.21**
Kodaikanal.*	21° 35′	0 59 43	4.03
Taungoo.*	21 44	1 00 03	3.93
Tiflis.	27 26	1 00 31	4.74
5 Caucasus Stations.	27 11	1 00 22	4.76
Irkutsk.	28 28	1 00 52	4.77
Mean.	**27 42**	**1 00 35**	**4.76**
Taihoku.	39 27	1 03 25	5.36
Batavia.*	42 35	1 05 33	5.01
Jurjew.	42 49	1 04 29	5.40
Manila.	43 34	1 05 03	5.29
Mean.	**41 57**	**1 04 19**	**5.35**

TABLE XI. *Cont.*

Station.	Epicentral Distance $= x$.	Time of commencement of 2nd P. T. $= t_2$.	v_2 Calculated by "Direct Method."
		h m s	Km/sec.
Tadotsu.	47° 02′	1 05 49	5.44
Upsala.	47 41	1 05 19	5.69
Kobe.	48 03	1 05 26	5.69
Osaka.	48 19	1 06 03	5.51
Laibach.	49 19	1 06 08	5.59
Messina.	49 46	1 06 15	5.60
Potsdam.	49 48	1 05 51	5.75
Triest.	49 52	1 05 43	5.80
Pola.	49 55	1 05 58	5.72
Leipzig.	50 16	1 05 53	5.79
Ischia.	50 30	1 06 14	5.69
Jena.	50 48	1 06 06	5.78
Rocca di papa.	51 15	1 06 09	5.80
Padova.	51 20	1 06 42	5.63
Tokyo.	51 26	1 06 25	5.73
Mizusawa.	51 39	1 06 28	5.74
Göttingen.	51 45	1 06 12	5.84
Querce.	51 54	1 06 24	5.79
Ximeniano.	51 55	1 05 47	6.01
Quarto-Castello.	51 56	1 06 02	5.92
Mean.	**50 12**	**1 06 03**	**5.73**
Mauritius.	55 15	1 07 03	5.93
Birmingham.	58 49	1 08 56	5.69
Paisley.	59 30	1 08 18	5.96
Mean.	**58 06**	**1 08 18**	**5.82**

TABLE XI. *Cont.*

Station.	Epicentral Distance $=x$.	Time of commencement of 2nd P. T. $=t_2$.	v_2 Calculated by "Direct Method."
		h m s	km/sec.
San Fernando.	66° 54′	1 11 42	5.66
Cape Town.	85 46	1 12 27	7.01 (?)
Mean.	**73 11**	**1 11 57**	**6.11**
Cheltenham.	105 22	1 23 22	5.81
Washington.	105 17	1 23 27	5.79
Mean.	**105 20**	**1 23 25**	**5.80**
Wellington.	115 45	1 29 54	5.34
Tacubaya.	128 47	1 28 03	6.23

The relation to the epicentral distance (x) of the time (t_2) of occurrence of the 2nd preliminary tremor is illustrated in Fig. 8, from which it will be seen that up to $x=$about 50° the rate of increase of the time relative to the distance was a little smaller than that of simple proportion, the maximum time deviation being about 1 min. Between $x=50°$ and $x=130°$, the relation seems to become more nearly one of proportion.

According to Table XI, the mean values of v_2 are as follows:—

		km/sec.	
(i)	$x=11°\ 20'$;	$v_2=4.52$	(Taschkent).
(ii)	13 34	4.21	(3 Indian Stations).
(iii)	27 42	4.76	(Tiflis and 5 Caucasian Stations).
(iv)	41 57	5.35	(Taihoku and Manila).
(v)	50 12	5.73	(20 Stations in Japan and Central Europe).
(vi)	58 06	5.82	(Mauritius and 2 British Stations).
(vii)	73 11	6.11	(San Fernando and Cape Town).
(viii)	105 20	5.80	(Cheltenham and Washington).
(ix)	128 47	6.23	(Tacubaya).

Of the above 9 groups, the x and v_2 for (v) have been obtained by taking the means from 20 stations in Japan, Italy, Austria-Hungary, Germany, and Sweden. As is graphically represented in Fig. 10, the velocity v_2 steadily increased with the epicentral distance, till it reached a value of 5.68 km per sec. for $x=50°16'$ (Group v), the mean rate of the velocity increase being about 0.038 km per degree of the distance. For the distances over about 60°, the rate of increase of the velocity seems to become smaller. The average value of the velocity, between $x=41°\,57'$ and $x=128°\,47'$, comes out to be **5.82** km per sec.

For the sake of comparison, the case of the San Francisco earthquake of April 18, 1906, is also illustrated in Fig. 10.*

To find out the dependence, if any, of v_2 on the nature of the path of seismic propagation, I give in the succeeding §§, the results of the velocity calculation, according to the "direct" and "difference" methods, for the different groups of stations (§ 85).

103. ***Group 1. Tacubaya, Colaba (Bombay), Kodaikanal (Madras).***

"Direct Method."

Station.	x	t_2-t_0	v_2
			km/sec.
Tacubaya.	128° 47′	38^m 15^s	6.23
Colaba.	13 28	6 51	3.64
Kodaikanal.	21 35	9 55	4.03

* The *Bulletin of the Imperial Earthquake Investigation Committee*, Vol. I, No. I, p. 37.

"Difference Method."

Combination of Stations.	δx	δt_2	v_2
			km/sec.
Tacubaya -Colaba.	115° 19′	31m 24s	6.80
„ -Kodaikanal.	107 12	28 20	7.01
Kodaikanal-Colaba.	8 07	3 04	7.27

104. *Group 2. Great Britain, North Germany, Batavia.*

"Direct Method."

Place.	x	t_2-t_0	v_2
		m s	km/sec.
Great Britain { Birmingham	58° 49′	19 08	
Great Britain { Paisley.	59 30	18 30	
Mean.	59 10	18 49	5.82
North Germany { Potsdam.	49 48	16 03	
North Germany { Leipzig.	50 16	16 05	
North Germany { Jena.	50 48	16 18	
North Germany { Göttingen.	51 45	16 24	
Mean.	50 39	16 13	5.79
Batavia.	42 35	15 45	5.01

"Difference Method."

Combination.	δx	δt_2	v_2
		m s	
Great Britain-North Germany.	8° 31′	2 36	6.07 km per sec.
„ -Batavia.	16 35	3 04	10.01
North Germany-Batavia.	8 04	0 28	(?)

105. ***Group 3. South Austro-Hungary, North Italy, Calcutta, Taungoo, New Zealand, Tiflis, Taschkent.***

"Direct Method."

Station.		x	t_2-t_0	v_2
			m s	
South Austro-Hungary.	Laibach.	49° 19′	16 20	km/sec.
	Triest.	49 52	15 55	
	Pola.	49 55	16 10	
Mean		**49 42**	**16 08**	**5.70**
North Italy	Padova.	51 15	16 21	
	Rocca di papa.	51 20	16 54	
	Querce.	51 54	16 36	
	Ximeniano.	51 55	15 59	
	Quarto Castello.	51 56	16 14	
Mean		**51 40**	**16 25**	**5.83**
Calcutta.		13 42	5 21	4.74
Taungoo.		21 44	10 15	3.93*
Wellington.		115 45	40 06	5.34
Tiflis.		27 26	10 43	4.74
Taschkent.		11 20	4 38	4.52

"Difference Method."

Combination of Stations.	δx	δt_2	v_2
		m s	km/sec.
S. Austro-Hungary-Taungoo.	27° 58′	5 53	8.80
„ -Tiflis.	22 16	5 25	7.61
„ -Taschkent.	38 22	11 30	6.18
„ -Calcutta.	36 00	10 47	6.18

Combination of Stations.	δx	δt_2	v_2
		m s	km/sec.
Wellington-S.Austro-Hungary.	66° 03′	23 58	5.10
„ -Calcutta.	102 03	34 45	5.44
„ -Taungoo.	94 01	29 51	5.83
„ -North Italy.	64 05	23 41	5.01
„ -Tiflis.	88 19	29 23	5.56
„ -Taschkent.	104 25	35 28	4.61
North Italy-S.Austro-Hungary.	1 58	00 17	(?)
„ -Calcutta.	37 58	11 04	6.36
„ -Taungoo.	29 56	6 10	9.00
„ -Tiflis.	24 14	5 42	7.88
„ -Taschkent.	40 20	11 47	6.34
Tiflis -Calcutta.	13 44	5 22	4.74
„ -Taungoo.	5 42	0 28	(?)
„ -Taschkent.	16 06	6 05	5.86
Taungoo -Calcutta.	8 02	4 54	3.03
„ -Taschkent.	10 24	5 37	3.43

106. ***Group 5. Taschkent, Jurjew (Dorpat), Upsala, Batavia.****

"Direct Method."

Station.	x	t_2-t_0	v_2
Taschkent	11° 20′	4m 38s	4.52 km/sec.
Jurjew (Dorpat)	42 49	14 41	5.40
Upsala.	47 41	15 31	5.69

* Batavia excepted. (See § 104).

"Difference Method."

Combination of Stations.	δx	δt_2	v_2
Upsala—Jurjew.	4° 52′	0m 50s	10.82(?)km/sec
„ —Taschkent.	36 21	10 53	6.19
Jurjew— „	31 29	10 03	5.81

107. ***Group 6. Japan, Taihoku, Tadotsu, Kobe, Osaka, Tokyo, Mizusawa.***

"Direct Method."

Place.	x	t_2-t_0	v_2
Taihoku.	39° 27′	13m 37s	5.36 km/sec.
Tadotsu.	47 02	16 01	5.44
Kobe.	48 03	15 38	5.69
Osaka.	48 19	16 15	5.51
Tokyo.	51 26	16 37	5.73
Mizusawa.	51 39	16 40	5.74

"Difference Method."

Combination of Stations.	δx	δt_2	v_2
Tokyo. Mizusawa. — Tadotsu. Kobe. Osaka.	3° 45′	0m 40s	10.40 km/sec.
„ — Taihoku.	12 06	3 01	7.43
Tadotsu. Kobe. Osaka. — „	8 21	2 21	6.57

108. ***Group 7. Tiflis; Ischia, Messina; Ximeniano, Querce, Quarto-Castello, Rocca di papa; San Fernando; Calcutta; Wellington.***

"Direct Method"

Stations.	x	t_2-t_0	v_2
		m s	km/sec.
Tiflis.	27° 26′	10 43	4.74
Ischia, Messina.	50 08	16 27	5.65
Ximeniano, Querce, Quarto-Castello, Rocca di papa.	51 45	16 17	5.88
San Fernando.	66 54	21 54	5.66
Calcutta.	13 42	5 21	4.74
Wellington.	115 45	40 06	5.35

"Difference Method."

Combination of Stations.	δx.	δt_2	v_2
		m s	km/sec.
Wellington - Tiflis.	88° 19′	29 23	5.57
„ - Ischia, Messina.	65 37	23 39	5.14
„ - San Fernando.	48 51	18 12	4.97
„ - Ximeniano, Querce, Quarto-Castello, Rocca di papa.	64 00	23 49	4.98
„ - Calcutta.	102 03	34 45	5.44
San Fernando - Tiflis.	39 28	11 11	6.53
„ - Ischia, Messina.	16 46	5 27	5.70
„ - Ximeniano, Querce, Quarto-Castello, Rocca di papa.	15 09	5 37	5.00
„ - Calcutta.	53 12	16 33	5.59
Ischia, Messina - Tiflis.	22 42	5 44	7.34
„ - Calcutta.	36 26	11 06	6.08

Combination of Stations.		δx	δt_2	v_2
Ximeniano, Querce, Quarto-Castello, Rocca di papa.	-Tiflis.	24° 19′	5 m 34 s	8.10 km/sec.
,,	-Calcutta.	38 03	10 56	6.45
Tiflis	- ,,	13 44	5 22	4.74

109. ***Group 8. Washington, Cheltenham, Tiflis, Kodaikanal, Batavia.***

"Direct Method."

Place.	x	t_2-t_0	v_2
Washington.	105° 17′	33 m 39 s	5.79 km/sec.
Cheltenham.	105 22	33 34	5.81
Tiflis.	27 26	10 43	4.74
Kodaikanal.	21 35	9 55	4.03
Batavia.	42 35	15 45	5.01

"Difference Method."

Combination of Stations.		δx.	δt_2	v_2
Washington Cheltenham	-Tiflis.	77° 54′	22 m 54 s	6.30 km/sec.
,,	-Kodaikanal.	83 45	23 42	6.54
,,	-Batavia.	62 45	17 52	6.50
Tiflis	-Kodaikanal.	5 51	0 48	13.52 (?)
Batavia	-Tiflis.	15 09	5 02	5.57
,,	-Kodaikanal.	21 00	5 50	6.67

110. ***Single Stations:— Manila, Mauritius, Cape Town.***

"Direct Method."

Place.	x	t_2-t_0	v_2
Manila.	43° 34′	15^m 15^s	5.29 km/sec.
Mauritius.	55 15	17 15	5.93
Cape Town.	85 46	22 39	7.01
Irkutsk.	28 28	11 04	4.77

SUMMARY.

111. ***v_2 for the different Groups, calculated by "Direct Method."*** The values of the velocity V_2 for the different stations, calculated by "direct method," are collected in Table XII.

TEBLE XII. v_2 calculated by "Direct Method."

Place.	Epicental Distance.	v_2
	Group 1.	
Colaba.	13° 28′	3.64 km/sec.
Kodaikanal.	21 35	4.03
Takubaya.	128 47	6.23
	Group 2.	
Batavia.	42° 35′	5.01
North Germany.	50 36	5.79
Great Britain.	59 10	5.82
	Group 3.	
Taschkent.	11° 20′	4.52
Calcutta.	13 42	4.74
Tiflis.	27 26	4.74
South Austro-Hungary.	49 42	5.70
North Italy.	51 40	5.83
Wellington.	115 45	5.34

Place.	Epicentral Distance	v_2
	Group 5.	
Taschkent.	11° 20′	4.52 km/sce.
Jurjew (Dorpat)	42 49	5.40
Upsala.	47 41	5.69
	Group 6.	
Taihoku.	39° 27′	5.36
Tadotsu.	47 02	5.44
Kobe.	48 03	5.69
Osaka.	48 19	5.51
Tokyo.	51 26	5.73
Mizusawa.	51 39	5.74
	Group 7.	
Calcutta.	13° 42′	4.74
Tiflis.	27 26	4.74
Ischia, Messina	50 08	5.65
Ximeniano, Querce, Quarto-Castello, Rocca di papa.	51 45	5.88
San Fernando.	66 54	5.66
Wellington.	115 45	5.35
	Group 8.	
Kodaikanal.	21° 35′	4.03
Tiflis.	27 26	4.74
Batavia.	42 35	5.01
Washington.	105 17	5.79
Cheltenham.	105 22	5.81
	Single Stations.	
Irkutsk.	28° 28′	4.77
Manila.	43 34	5.29
Mauritius.	55 15	5.93
Cape Town.	85 46	7.01

Taking for the different groups the mean values of v_2, for the x above about 40°, we find :—

Group	(1)....	Mean	$x=128°\ 47'$;	$v_2=6.23$ km/sec.	(Tacubaya only).
„	(2)	„	$x=52\ 25$;	$v_2=5.65$	„
„	(3)	„	$x=63\ 42$;	$v_2=5.68$	„
„	(5)	„	$x=45\ 15$;	$v_2=5.55$	„
„	(6)	„	$x=48\ 12$;	$v_2=5.60$	„
„	(7)	„	$x=67\ 15$;	$v_2=5.68$	„
„	(8)	„	$x=92\ 47$;	$v_2=5.64$	„

Thus the Group I (Tacubaya) observation gives a velocity of 6.23 km/sec. for the distance of $x=128°\ 47'$. For all the other groups, whose mean distance x was from $45°\ 15'$ to $92°\ 47'$, the velocity v_2 remained very nearly constant, varying only between 5.55 and 5.68 km/sec. Taking the average of the values of the velocity for the groups (2) to (8), we obtain, for $x=40°$ to $115°\ 45'$:—

Mean $x=61°\ 36'$, $v_2=$**5.63** km/sec. (direct method).

Again, taking only the observations relating to Great Britain, North Germany, North Italy, South Austria-Hungary, and Tokyo, and Mizusawa, we obtain :—

(i)	Great Britain, North Germany.	$x=54°\ 53'$;	$v_2=5.81$ km/sec.
(ii)	North Italy, South Austria-Hungary.	$x=50°\ 41'$;	$v_2=5.77$ „
(iii)	Tokyo, Mizusawa, (Japan).	$x=51°\ 33'$;	$v_2=5.74$ „

Thus again, for these sets of stations, for which the distance was nearly alike ($x=50°\ 41'$ to $54°\ 53'$), the velocity v_2 varied only between 5.74 km/sec. for Japan to 5.81 km/sec. for Great Britain and North Germany. If, however, these slight differences in the value of v_2 denote anything, we may conclude from the above three sets, (i), (ii), and (iii), and the Group I, as follows :—The propagation velocity v_2 was greatest along the suboceanic path,

through the North Pole, and was slightly greater along the flat region path to Great Britain and North Germany than along the mountainous path to North Italy and South Austria-Hungary, being least along the path to Japan across the plateau of Tibet.

112. ***Average Value of v_2 calculated by "Difference Method."*** Taking from Table XI, the mean values of the time (t_2) of commencement of the 2nd preliminary tremor corresponding to different epicentral distances over 27° 42′ (§ 102), and calculating by the Method of Least Squares, we obtain, for $x=27°\,42'$ to $128°\,47'$:—

$$v_2 = \mathbf{6.46}\ \text{km/sec.};$$

this having no particular reference to the paths of the seismic propagation.

Chapter VI. Velocities of Propagation of the Principal Portion.

113. In this Chapter I will consider the transit velocities of the vibrations at the commencement of the 3rd and 5th sections, or the 1st and 3rd phases of the principal portion, and that of the absolute maximum indicated in the Milne horizontal pendulum seismograms.

114. ***Transit Velocity (v_3) of the 1st Phase of Principal Portion.*** Table XIII gives for the 12 stations of Taihoku, Tadotsu, Osaka, Tokyo, Leipzig, Göttingen, Rocca di papa, Quarto-Castello, Birmingham, Cheltenham, Washington, and Tacubaya, the epicentral distance (x), the time (t_3) of commencement of the principal