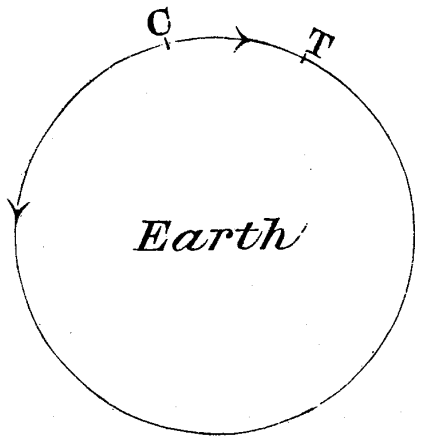
may be, as Professor H. Nagaoka suggests, one of the maximum transit velocity; or may mark the limit beyond which the seismic waves are, on account of certain physical properties of the underlying medium, unable to penetrate. Further, the consideration on the transit velocity of the Caracas earthquake of 1900 (§ 55) seems to indicate that, the waves with the transit velocity v_2 also travel along a layer parallel to the surface of the earth.

That the waves with the transit velocity v_5, or those in the 3rd phase of the principal portion, travel along the surface of the earth is perfectly evident. (See also § 46.)

XV. Propagation of Seismic Waves completely round the Earth.

§ 44. Let T (Fig. 9) be the observing station (Tōkyō), and C the earthquake origin. Then there are three sets of motion, which

Fig. 8.



we may call respectively W_1, W_2, and W_3 waves, as follows:—*firstly*, the W_1 waves are those propagated from C to T along the shortest *surface* path; *secondly*, the W_2 waves are those propagated from C in the opposite direction and reach T after passing through the antipode of C; and *thirdly*, the W_3 waves are the W_1 waves propagated further in the same direction, beyond T, and again reach

the latter after once completely travelling round the earth. (Fig. 9, which is the NS component diagram of the Turkestan earthquake of Aug. 22, 1902, recorded at Hongō, Tōkyō, indicated the W_2 and W_3 waves distinctly.)

The identification of the W_3 waves is possible only in a very few number of cases; that of the W_2 waves is, however, more definite, being usually characterized by the fact that their period is much slower than those of the preceding vibrations, which form the *end portion* of the W_1 waves, or the earthquake proper.

Table XXXVII gives the time observations in Tōkyō relating to the three sets of waves, W_1, W_2, and W_3, in cases of the twelve distant earthquakes, of which the first nine, (b), (c), (e), (f), (g), (h), (i), (j) and (k), are the same as those considered in the previous section, while the remaining three, (l), (m) and (n), have been newly added.

Fig. 9. Turkestan Earthquake of Aug. 22, 1902; 0.9.33. p.m.

NS Component. Multiplication=10.

(Observed with Omori's Horizontal Pendulum at Hongô, Tôkyô.)

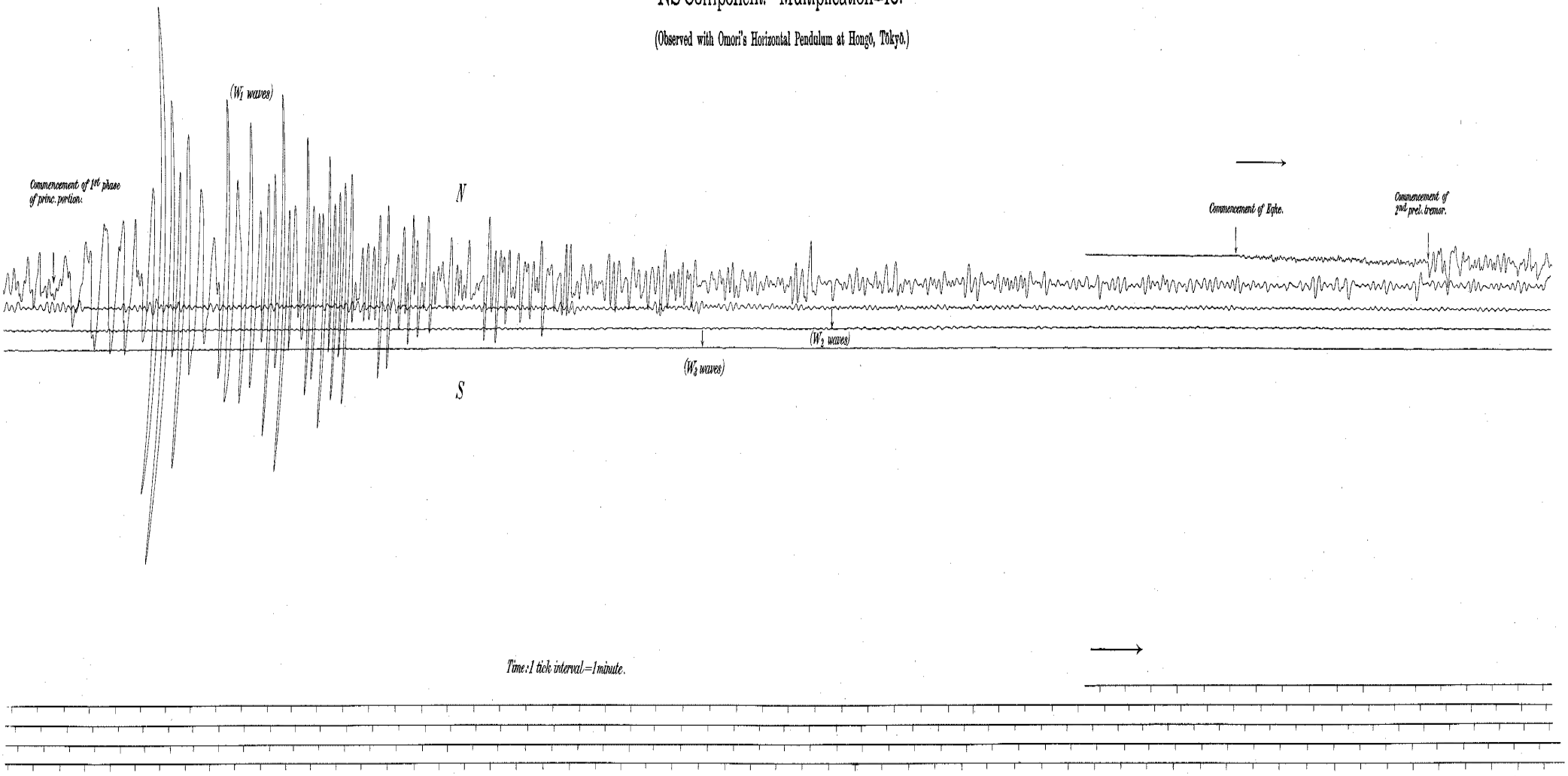


TABLE XXXVII.

EARTHQUAKES PROPAGATED ROUND THE EARTH.*

Eq. No.	Date.	Origin.	Commencement of the eqke.	3rd phase of the princ. portion.	Commencement of W_2 waves.	Commencement of W_3 waves.
			h m s	h m s	h m s	h m s
b	Sept. 11,1899.	Alaska.	6. 50. 58 a.m.	7. 10. 01 a.m.	9. 18. 48 a.m.	—
c	„ 20, „	Aidin.	11. 24. 27 a.m.	11. 58. 46 a.m.	1. 05. 34 p.m.	—
e	Jan. 20,1900.	Mexico.	3. 52. 39 p m.	4. 30. 13 p.m.	5. 20. 50 p.m.	—
f	Sept. 18, „	—	7. 1. 41 a.m.	7. 14. 31 a.m.	9. 48. 41 a.m.	—
g	Oct. 9, „	Alaska.	9. 37. 14 p m.	9. 53. 46 a.m.	0. 27. 36 p.m.	—
h	„ 29, „	Caracas.	6. 29. 22 p.m.	7. 16. 55 p.m.	8. 08. 47 p.m.	—
i	April 19,1902.	Guatemala.	11. 38. 47 a.m.	0. 20. 24 p.m.	1. 01. 36 p.m.	—
j	Aug. 22, „	Kashgar.	0. 9. 33 p.m.	0. 28. 01 p.m.	2. 55. 18 p.m.	3. 50. 15 p.m.
k	Sept. 22, „	Guam.	10. 52. 16 a.m.	10. 58. 22 a.m.	1. 52. 39 p.m.	2. 12. 24 p.m.
l	June 22,1900.	—	6. 11. 09 a.m.	6. 54. 29 a.m.	—	9. 47. 49 p.m.
m	July 29, „	—	4. 08. 42 p.m.	4. 26. 33 p.m.	—	8. 20. 02 p.m.
n	Aug. 14, „	—	5. 19. 39 a.m.	5. 26. 25 a.m.	8. 00. 28 a.m.	—

§ 45. *Period and Range of motion of the W_1, W_2 and W_3 waves.* Table XXXVIII gives the period and the maximum range of motion of the three sets of waves, namely, W_1, W_2, and W_3 waves, in the twelve earthquakes contained in Table XXXVII; the part of the W_1 waves taken for comparison being the 3rd phase of the principal portion.

1. *Period.* The average period of the W_2 waves is with a few exceptions very uniform, and gives a mean value of 20,4 sec., which is identical with the predominating period in the 3rd phase of the principal portion (see also § 39); the period of the W_3 waves being probably nearly the same as that of the W_2 waves. These facts seem to indicate that the W_2 and W_3 waves are the same vibrations

* The times are given in the 1st Normal Japan Time.

which constitute the 3rd phase of the principal portion of the earthquake proper. That this is probably the case may easily be understood, as the vibrations in the 3rd phase of the principal portion have large amplitude, while their period is tolerably slow, but not so very long as that of the waves in the 1st and the 2nd phases of the same portion.

2. *Amplitude.* The amplitude of the W_2 waves is generally very much smaller than that of the W_1 waves; the motion of the W_3 waves being again much smaller than that of the W_2 waves. This ought of course to be the case, as the intensity of the seismic waves rapidly decreases with an increase of distance from the centre of disturbance.

TABLE XXXVIII.

MAX. 2a AND AVERAGE PERIOD IN THE W_1, W_2 AND W_3 WAVES.

Eqke. No.	3rd phase. of princ. portion.		W_2 waves.		W_3 waves.	
	Max. 2a.	Principal Aver. period.	Max. 2a.	Aver. period.	Max. 2a.	Aver. period.
	mm	sec.	mm	sec.	mm	sec.
b	3,2	20,7	0,05	24,7	—	—
c	0,9	24,3 18,3	0,03	15,9	—	—
e	0,25	21,0	0,13	20,3	—	—
f	2,20	22,4	0,04	19,2	—	—
g	1,50	21,4	Small.	21,4	—	—
h	1,04	21,9	0,54	22,5	—	—
i	0,63	20,1 34,3	0,31	28,4	—	—
j	5,70	18,0	0,07	17,6	Small.	—
k	—	—	Small.	19,5	Small.	19,5
l	0,38	19,3	—	—	0,05	19,2
m	4,3	22,9	—	—	Small.	13,9
n	0,49	8,8	Small.	14,9	—	—
Mean *	mm 1,87	s **20,6**; 8,8; 24,3; 34,3	mm 0,12	**20,4**	—	**19,4**; 13,9

* The period most frequently occurring are prin ed in fat charac'ers.

§ 46. *Velocity of propagation of the W_2 and the W_3 waves.* Table XXXVIII contains the necessary data for the calculation of the transit velocity of the W_2 and W_3 waves; the significations of the different symbols being as follows:—

x = shortest *surface* distance between Tōkyō and the origin of an earthquake;

$\triangle T'$ = time difference between the occurrence of the W_2 waves and that of the 3rd phase of the principal portion;

$\triangle T''$ = time difference between the occurrence of the W_3 waves and that of the 3rd phase of the principal portion.

TABLE XXXIX.

CALCULATION OF THE TRANSIT VELOCITY OF THE W_2 AND THE W_3 WAVES.

Eqke. No.	Total duration of 1st and 2nd prel. tremors	km x	km km $40000-2x$	W_2 waves.		W_3 waves.	
				$\triangle T'$	Transit velocity.	$\triangle T''$	Transit velocity.
	m s			h m s	$\frac{km}{sec.}$	h m s	$\frac{km}{sec.}$
b	14. 13	6100	27800	2. 08. 47	3,6	—	—
c	22. 19	9200	21600	1. 06. 48	5,4	—	—
e	21. 40	11000 (?)	18000 (?)	0. 50. 37	5,9 (?)	—	—
f	9. 04	4300*	31400	2. 34. 10	3,4	—	—
g	12. 27	5600*	28800	2. 33. 50	3,1	—	—
h	32. 31	14200	11600	0. 51. 52	3,7	—	—
i	30. 20	12200 (?)	15600 (?)	0. 41. 12	6,3 (?)	—	—
j	13. 30	5700	28600	2. 27. 17	**3,2**	3. 22. 14	**3,3**
k	4. 04	2200	35600	2. 54. 17	3,4	3. 14. 02	3,4
l	33. 30	13900*	12200	—	—	2. 53. 20	3,8
m	12. 17	5600*	28800	—	—	3. 53. 29	2,9
n	4. 50	2600*	34800	2. 34. 03	3,8	—	—
Mean.	—	—	—	—	3,7 $\frac{km}{sec.}$	h m s 3. 20. 46	3,4 $\frac{km}{sec.}$

* The distances (x) marked with *asterisks* have been calculated by the formula x km $= 6{,}54\ y$ sec. $+ 720$ km.

The transit velocity of the W_2 waves is given by the equation: velocity $= \frac{40000^{km} - 2x^{km}}{\triangle T''}$; while the transit velocity of the W_3 waves is given by the equation: velocity $= \frac{40000^{km}}{\triangle T''}$, the circumference of the earth being supposed roughly to be 40000 km. The mean values of the transit velocity is found to be $3{,}7 \frac{km}{sec.}$ for the W_2 waves and $3{,}4 \frac{km}{sec.}$ for the W_3 waves. These results, which are very gross approximations, are to be interpreted as indicating the transit velocity of $3{,}3 \frac{km}{sec.}$. In fact, the Turkestan earthquake (Eqke *j*), which showed clearly the commencement of the W_2 and W_3 waves, gave the velocities of 3,2 and 3,3 $\frac{km}{sec,}$ respectively for these two sets of waves.

The mean value of $\triangle T''$, which ought to be constant, is 3 h 20 m 46 s, being the time required by the seismic waves, whose velocity is v_5, to travel once completely round the earth.

XVI. Longitudinal and Transverse Vibrations.

§ 47. In the strong motion area of great destructive earthquakes, the directions of the maximum motion at the different places converge, or are symmetrical, to the epifocal region. Again, it is well known that the macro-seismic motion at great distances from the origin consists mainly of horizontal vibrations. These facts seem to show that the most active part of the earthquake motion consists of the longitudinal waves; and we may suppose, therefore, that v_5, which is the transit velocity of the most active portion in the macro-seismic disturbances and also of the 3rd phase of the principal portion in distant earthquakes, characterizes the longitudinal component of the seismic motion. We have, however, no reason to suppose that