

east of the Island of Porto Rico. The instruments are placed on stone piers laid in cement extending 30 inches below the level of the floor. They are about 130 feet above sea level. The result of the observation was as follows.*

Phase of Motion.	NS Component. (Time of Commencement)	EW Component. (Time of Commencement)
1st Prel. Tremor.	^h 1 ^m 10 ^s 26	^h 1 ^m 10 ^s 25
Principal Portion.	1 50 48	1 43 25
Maximum.	2 10 48 ($2a=1.2$ mm)	2 13 51 ($2a=1.6$ mm)
End.	3 47 26	3 38 25

Chapter III. Milne Horizontal Pendulum Diagrams of the Kangra Earthquake.

63. Milne Horizontal Pendulum Stations. The present Chapter contains descriptions of the Milne Horizontal Pendulum Seismograms obtained at the following 19 stations:—Shide; Kew; Liverpool (Bidston); Edinburgh; Paisley; San Fernando; Wellington; Christchurch; Mauritius; Cape of Good Hope; Toronto; Victoria, B.C.; Baltimore; Calcutta; Kodaikanal; Bombay (Colaba); Bairût; Ponta Delgada; Honolulu. The analysis has been made of the photographic copies, except in the cases of the 3 last places whose diagrams I have not received. The reproduction of the registers are given in Pls. XVIII to XXII, the *Publications*, No. 23.

* Reproduced from Professor Reid's paper given in the *Terrestrial Magnetism and Atmospheric Electricity*.

The Milne horizontal pendulums are, according to the instructions from the British Association, usually so placed that the boom is in the meridian or points N-S, the natural oscillation period being about 15 sec. The magnification with respect to the horizontal earthquake motion is 6 to 7 times.

64. Utility of Milne Horizontal Pendulum. The Milne Horizontal Pendulum has rendered an invaluable service to the development of Seismology, a science practically founded on its modern basis by Professor John Milne, who pursues the subject with indefatigable energy and zeal. The instrument is simple in construction, and enables us to see some interesting features in the earthquake motion, which are not so obviously shown by other seismographs. In the present case, the records obtained at 5 British stations, San Fernando, Christchurch, Wellington, and some other places are very satisfactory.

65. Time of Occurrence and Duration. The times of occurrence of the different phases and the total duration of the Kangra earthquake of April 4, 1905, observed at the different stations, as given in Professor Milne's Circular, No. 13, are contained in the following table.

TABLE VIII. Indian Earthquake of April 4, 1906, observed with Milne Horizontal Pendulums.

(Extract from Professor Milne's Circular, No. 13.)

Station.	P. T. Commence.	Max.	Max. Amplitude.	Duration.
Shide. (B)	^h 1 ^m 1.0	^h 1 ^m 30.0	^{mm} 15.0 = <i>a</i>	^h 3 ^m 55 (2nd max. 1 ^h 54 ^m later)
" (C)	1 6.2	1 22.7	13.0	3 45 (2nd max. 2 ^h 9 ^m & 2 ^h 14 ^m later)

(B: period 25 sec.; C: period 20 sec.)

Station.	P. T. Commence.	Max.	Max. Amplitude.	Duration.
Kew Observatory.	1 ^h 0.2 ^m	1 ^h 29.2 ^m	15.3 ^{mm}	3 ^h 48 ^m
Liverpool Ob., Bidston.	0 58.8	1 30.6	11.6	4 22
Royal Ob., Edinburgh.	1 0.0	1 31.5	16.0	3 43
The Coats Ob., Paisley.	1 0.4	1 30.7	>14.0	3 40
San Fernando.	1 2.5	1 34.0	8.75	3 45½
Ponta Delgada, St. Miguel, (Azores.)	1 1.0	1 54.5	2.3	2 32½
Royal Ob., Cape of G. H.	1 2.0	1 46.0	3.0	2 10
Alipore Observatory.	0 52.	?	?	3 39
Bombay (Colaba).	0 52.9	—	—	4 19.6
Kodaikanal.	0 55.6	—	>22.0	3 36
Batavia.	0 58.6	1 1.9	7.0	3 —
Baltimore.	1 15.0(?)	2 10.0	3.0	
Beirût, Syria.	0 58.0	1 24½	18.5	3 59
Toronto.	1 14.0(?)	1 54.3	4.0	3 25.8
Victoria, B. C.	1 14.0	1 51.1	6.3	3 26.3

In the analysis of the Milne horizontal pendulum record, the period of vibration has been measured, in several cases, by the use of a magnifying lens. The $2a$ always denotes the motion as actually traced on the photogram.

66. British Stations and San Fernando. For the sake of comparison let us first describe the seismographs obtained at the 5 British stations of Shide, Kew, Bidston, Edinburgh, and Paisley, and the Spanish station of San Fernando. The records at these places are given in Pls. XVIII and XIX, the *Publications*, No. 23.

67. *Shide*, Newport, Isle of Wight, England.

(Professor J. Milne, F.R.S. Assistant, S. Hirota).

The earthquake was recorded by two instruments *B* and *C*, of the following constants :—

B. Period=25 sec. 1° turn=9 mm.

C. Period=20 sec.

C pendulum is without a calibrating screw.

B records N. S. motion, while *C* records E. W. motion.

Horizontal Pendulum B. Commencement=1^h 1.0^m In the strongest part, $T=26.0$ sec. (pendulum oscillations), the max. trace of 22 mm having occurred at 1^h 30.0^m. The motion was more or less active till 2^h 34.5^m, becoming thereafter very small, till the commencement of the W_2 group.

The latter first appeared at 3^h 4.6^m and the max. trace of 2.5 mm was gradually reached at 3^h 23.4^m; there being in the interval altogether 6 max groups, at an average interval of about 3^m 52^s. The W_2 motion may be regarded as having lasted about 54^m.

A slight thickening of the line at about 4^h 37^m may correspond to the W_3 motion.

Hor. Pendulum C. Commencement=1^h 6.2^m. In the strongest portion, $T=21$ sec. (pendulum oscillations), the max. trace of 27 mm having occurred at 1^h 22.7^m. The motion was more or less active till 2^h 40^m, becoming thereafter much smaller.

The diagram is somewhat different from that described above, especially in the W_2 group, which first began at 3^h 8.6^m. For the next 12^m 24^s, the motion was small and doubtful. Then, at 3^h 20^m 24^s, there occurred a small maximum (which is marked *a* in the diagram). For the next 27^m the motion was well defined and consisted of a number of max. movements (marked

b, c, d, e, f). These small groups, *a* to *f*, can be identified in the B-pendulum record, although the amplitudes differ much in the two diagrams. The greatest $2a$ of 3.6 mm took place at 3^h 38.7^m. For the next 14^m 30^s, the motion was much smaller but nearly constant, the W_2 group having lasted altogether 1^h 6^m.

The W_3 group occurred at about 4^h 32.5^m.

68. Kew, England. National Physical Laboratory, Kew Observatory. (Director, R.T. Glazebrook, D. Sc., F.R.S.; Superintendent, C. Chree, LL. D., F.R.S.; Observer, E. G. Constable.)

Commencement=1^h 0.2^m. Total Duration=3^h 48.1^m.

1st and 2nd Preliminary Tremors. The entire Duration=13.6^m. For the first 4.5^m the motion was very small. Then the motion increased slightly and remained nearly constant for the next 4.2^m. During the remaining 4.9^m the motion was again slightly larger, there being 4 maximum groups, which occurred at an average interval of 1^m 38.

Principal and End Portions. For the first 1.5^m the motion gradually swelled up to a max. $2a$ of 3.5 mm, being the result of the proper oscillations of the pendulum. For the next 1.5^m the motion was small. For the next 4.0^m the motion was larger, the max. $2a$ of 4.4 mm occurring at the commencement.

For the next 2.6^m the motion was smaller; there being several minimum epochs, probably due to the appearance of slow vibrations, which prevented the pendulum from swaying into the proper oscillation. The time of commencement of this phase was 20.2^m after the beginning of the earthquake.

Then, at 1^h 23.2^m, there appeared a maximum group, which lasted 5.9^m and was composed of 2 subdivisions. This was followed by a minimum, and then by the absolute maximum

group, which lasted 3.0^m and whose greatest $2a$ of 30.6 mm occurred at $1^h 29.2^m$.

Thereafter the motion was much smaller and remained for the next 28.6^m on the whole constant; there being 7 max. groups, whose average interval was 4.1^m and of which the 3rd one had the greatest $2a$ of 13 mm. For the next 7.0^m , the motion was smaller:—max. $2a=3.0$ mm. For the next 21.8^m the motion was again larger (max. $2a=8$ mm); there being a series of maximum groups. (The end of this epoch was at $2^h 28.2^m$.) The subsequent motion was much smaller (max. $2a=2.0$ mm), the amplitude remaining for the next 50^m nearly constant. For the next 30^m the motion was small, being nearly the same as in the 2nd stage of the preliminary tremor.

W_2 . The W_2 motion began at $3^h 36.9^m$, when the motion became larger again and remained active for the next 27^m , comprising a number of max. groups. The greatest $2a$ was 2.6 mm.

69. Bidston (Liverpool), England. Liverpool Observatory. (Director, W. E. Plummer.) Time of Commencement= $1^h 0^m 36^s$. Total Duration= 4^h .

The motion during the successive epochs was as follows:—

- (i) For 3.1^m : small, but distinct.
- (ii) „ 4.6^m : larger, max. $2a=1.0$ mm.
- (iii) „ 2.9^m : max. $2a=2.0$ mm, occurred at the commencement.
- (iv) „ 6.0^m : there were 5 small maximum groups, the 3rd and 4th having the max. $2a$ of 3.0 mm. $T=21.2$ sec.
- (v) „ 6.7^m : the motion gradually reached a max. $2a=4.5$ mm, there being, however, among it some alternations of max. and min. $T=19.2$ sec.

So far the motion lasted 23.3^m and may be regarded as

roughly corresponding to the 1st and 2nd preliminary tremors and the 1st and 2nd phases of the principal portion.

- (vi) For 3.7^m: there was a single group, the motion gradually reaching a max. $2a=12.6$ mm, and again gradually diminishing to a minimum. This epoch, which commenced at 1^h 23^m 54^s, probably corresponds to the 3rd phase of the principal portion, the maximum motion having occurred at 1^h 28^m 54^s. $T=18.3$ sec.
- (vii) For 3.6^m: there were 4 max. groups, of which the 3rd had the max. $2a$ of 11.4 mm. $T=19.4$ sec.
- (viii) For 3.3^m: there was a single group, gradually reaching the absolute max. $2a=20.0$ mm, at 1^h 29^m 48^s.
- (ix) For 30.8^m: the motion remained on the whole constant (max. $2a=11.0$ mm), there being a series of max. groups. At the middle of this epoch, T was 18.8 sec.
- (x) For 13.4^m: there was not much alternation of max. and min. groups, the $2a$ diminishing to 1.9 mm; $T=18.2$ sec.

The subsequent motion was much smaller, and may be taken as the *end portion*:— $T=18.2$ sec. Among a number of max. groups, there were two well defined ones, as follows:—

- (1) $2a=2.0$ mm, between 2^h 22^m 0^s and 2^h 35^m 12^s;
- (2) $2a=1.6$ „ „ „ 2 39 36 and 2 49 36.

W_2 . The W_2 motion appeared at 3^h 28^m 58^s, there being, for the next 13^m 18^s, a continuous max. group, till 3^h 44^m 6^s. The max. $2a$ of 4.2 mm occurred at 3^h 37^m 48^s; $T=17.5$ sec. The subsequent motion was smaller. The period T was 21.2 sec. in the epoch corresponding to the earlier part of the 2nd preliminary tremor, and 17.5 sec. in what may correspond to the 3rd phase of the principal portion of the W_2 motion. The 6 other values of the period given above varied between 18.2 and 19.4 sec.,

the average being 18.7 sec., which evidently represents the oscillation period of the pendulum.

70. *Edinburgh*, Scotland. Royal Observatory. (Director, Dr. R. Copeland. Observer, Thomas Heath.)

Time of Commencement = $1^{\text{h}} 0^{\text{m}} 0^{\text{s}}$. Total Duration = $3^{\text{h}} 43^{\text{m}}$.

The Edinburgh diagram is very much similar, almost group for group, to that obtained at Kew. The instruments at these two stations had probably nearly equal oscillation periods. The movements in the successive stages of motion were as follows:—

- (i) For 6.5^{m} : the motion was very small.
- (ii) „ 6.0^{m} : the motion rapidly reached a max. $2a$ of 4.0 mm, at 2.0^{m} from the commencement, thence being gradually reduced to a minimum.
- (iii) „ 5.2^{m} : a max. $2a$ of 5.5 mm was gradually reached at 3.0^{m} from the commencement, thence being again reduced to a minimum.
- (iv) „ 5.0^{m} : there was an ill defined max. group, $2a = 3.5$ mm.

So far the motion altogether lasted 22.7^{m} and corresponds to the 1st and 2nd preliminary tremor and the 1st and 2nd phases of the principal portion. The following three epochs, (v) to (vii), which began at $1^{\text{h}} 22.6^{\text{m}}$, and together lasted 9.7^{m} probably corresponds to the 3rd phase of the principal portion.

- (v) For 2.2^{m} : there was a single max. group, $2a = 10.0$ mm.
- (vi) „ 2.9^{m} : there were two max. groups, each having max. $2a$ of 18.0 mm.
- (vii) „ 4.6^{m} : the motion was most active and consisted of two main groups, the 2nd having max. $2a$ of 32 mm, which occurred at $1^{\text{h}} 31.5^{\text{m}}$.
- (viii) „ 21.0^{m} : the motion became much smaller (max. $2a = 8.0$ mm),

there being a series of about 11 max. groups, whose average interval was 2.1^m .

- (ix) For 9.5^m : there were 5 max. groups (max. $2a=6.0$ mm), with an average interval of 1.9^m . The 1st 3 groups are nearly amalgamated into one continuous maximum.
- (x) „ 7.3^m : there was a continuous max. group, max. $2a=5.0$ mm.
- (xi) „ 2.0^m : a small max. group, $2a=3.0$ mm.
- (xii) Then followed a max. group, whose max. $2a=6.0$ mm occurred at $2^h 13.4^m$.
- (xiii) The subsequent max. groups were more or less active (max. $2a=2.5$ mm) up to $2^h 39.9^m$.
- (xiv) For 34.3^m : the motion was on the whole constant; max. $2a=1.4$ mm.
- (xv) „ 33.3^m : the motion was smaller, and nearly constant; max. $2a=1.0$ mm.

W_2 . The W_2 motion appeared at $3^h 46.9^m$, forming a max. group for about 13.3^m ; max. $2a=2.0$ mm.

71. Paisley, Scotland.

The Coats Observatory. (Superintendent, David Crilley.)

Time of Commencement= $1^h 0.0^m$. Total Duration= $3^h 10^m$.

1st Preliminary Tremor. Duration= 8.3^m . The motion was very small during the first 4.1^m .

The subsequent movements were as follows.

- (i) For 11.3^m : the motion was large; max. $2a=3.7$ mm.
- (ii) „ 4.6^m : the motion was again smaller.
- (iii) „ 13.7^m : the most active part of motion, commencing at $1^h 23.9^m$. The max. group, ($2a=32.5$ mm,) occurred at $1^h 31.2^m$.
- (iv) „ 12.2^m : the motion was smaller, but still active; max. $2a=10$ mm.
- (v) „ 29.6^m : the motion was nearly constant; max. $2a=5.0$ mm.

Thereafter the motion became again smaller, being, however, more or less active till 3^h 18^m.

W_2 . The W_2 motion began at 3^h 48.4^m, there being, during the next 18.5^m, two main groups, $2a$ of the first being 1.8 mm.

72. *San Fernando*, Spain.

Instituto y Observatorio de Marina. (Director, Capitán de Fragata Tomás de Azcárate.)

Time of Commencement=1^h 2.5^m. Total Duration=3^h 46^m.

The San Fernando seismogram is much similar to those obtained at Edinburgh and Kew; especially, between the commencement of the 3rd phase of the principal portion and about 2^h 30.7^m, and also in the *end portion*, the San Fernando and Kew diagrams are almost identical group for group.

The motion was very small during the first 9.2^m. Then, at 1^h 12.3^m there took place the first max. group ($2a=2.0$ mm). What may be regarded as the 3rd phase of the principal portion began at 1^h 27.1^m. The times of occurrence and the $2a$'s of the successive maximum movements are given in the following list.*

Time.	Max. $2a$.	Time.	Max. $2a$.
^h ^m	^{mm}	^h ^m	^{mm}
1 16.0	2.50	1 45.5	5.25
1 23.0	3.75	1 57.5	6.25
1 26.0	4.25	2 1.5	5.50
1 29.0	8.75	2 6.5	4.25
1 34.0	8.75	2 14.0	4.25
1 36.0	6.75	2 23.0	2.25
1 39.0	7.25	3 38.5	2.00
1 41.0	6.25	3 46.0	1.50
1 42.0	6.25		

* This list was kindly furnished by Cap. Azcárate.

W_2 . The W_2 motion began at 3^h 30.7^m, lasting for about 20^m. The max. $2a$ was 3.7 mm.

73. *New Zealand Records.*

The seismograms obtained at Wellington and Christchurch are reproduced in Pl. XXI, the *Publications*, No. 23. Some of the more prominent maxima identified in the two records are marked by the letters a, b, c, \dots, x, y, z .

74. *Wellington, New Zealand.* (Observer, G. Hogben, M. A.)

Time of Commencement=1^h 9.8^m. Total Duration=3^h 40^m.

For the first 10.0^m, the motion was extremely small. At 1^h 17.5^m there took place a very slight maximum, the motion for the next 2.2^m being again small. Then took place the first well defined maximum motion. This, marked a , and the subsequent maxima, marked b, c, \dots, y, z , were as follows:—

{	$a.$1 ^h 19.8 ^m ,	$2a=1.2$ mm
	$b.$	1 25.6 ,	$2a=2.1$
	$c.$	1 26.9 ,	$2a=1.1$
	$d.$	1 29.9 ,	$2a=1.8$

The epoch between the commencement and d , whose duration was 20.1^m, probably corresponds to the 1st preliminary tremor. For the next 13.6^m, the motion consisted of a series of small maximum groups, the greatest being the following:—

$e.$1 ^h 41.8 ^m ,	$2a=3.0$ mm
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Judging from the Christchurch diagram, the subsequent portion seems to be made up of long period vibrations, and the next 17.1^m probably corresponds to the 1st and 2nd phases of the principal portion. For the first 8.9^m of this portion the motion was small, the max. $2a$ being 5.0 mm. For the remain-

ing 8.2^m, the motion was much greater, the two last maxima being as follows:—

$$\left\{ \begin{array}{l} f. \dots 1^h 57.6^m, \quad 2a=13.6 \text{ mm} \\ g. \quad 1 \ 59.9, \quad 2a=11.6 \text{ ,,} \end{array} \right.$$

For the next 14.8^m, which probably corresponds to the 3rd phase of the principal portion, the motion consisted essentially of 2 groups of maxima, which lasted 5.6 and 7.0^m respectively, the two being separated by a minimum whose duration was 2.2^m. The 1st group consisted of 3 sub-maxima, whose first and 3rd ones were as follows:—

$$\left\{ \begin{array}{l} h. \dots 2^h 2.2^m, \quad 2a=23.0 \text{ mm} \\ i. \quad 2 \ 4.9, \quad 2a=21.0 \text{ ,,} \end{array} \right.$$

The 2nd group also consisted of 3 maxima, whose first two were as follows:—

$$\left\{ \begin{array}{l} j. \dots 2^h 10.1^m, \quad 2a=21.0 \text{ mm} \\ k. \quad 2 \ 11.9, \quad 2a=26.0 \text{ ,,} \end{array} \right.$$

Thereafter the motion became much smaller and consisted, for the next 13.2^m, of 7 max. groups, the first of which has a max. $2a$ of 6.8 mm: the times of occurrence of the maximum movements being as follows:—

$$\left\{ \begin{array}{ll} l. \dots 2^h 16.8^m & p. \dots 2^h 24.5^m. \\ m. \quad 2 \ 18.8 & q. \quad 2 \ 26.5 \\ n. \quad 2 \ 20.5 & r. \quad 2 \ 27.3 \\ o. \quad 2 \ 21.5 & \end{array} \right.$$

W_2 . The W_2 motion appeared at 2^h 29.3^m and continued for 15.4^m, there being two well defined max. groups, as follows:—

$$\left\{ \begin{array}{l} s. \dots 2^h 29.3^m, \quad 2a=5.0 \text{ mm;} \\ t. \quad 2 \ 34.8, \quad 2a=2.0 \text{ ,,} \end{array} \right.$$

For the next 29.5^m, the motion consisted of a series of detached maxima (greatest $2a=2.4$ mm), some of which occurred as follows:—

$$\left\{ \begin{array}{ll} u \dots 2^h 54.1^m & w \dots 3^h 1.9^m \\ v \quad 2 \quad 56.1 & x \quad 3 \quad 12.6 \end{array} \right.$$

For the next 14.0^m, the motion was small.

„ „ 11.3^m, there was a series of max. groups, of which the greatest was the following :—

$$y \dots 3^h 35.7^m, \quad 2a = 2.0 \text{ mm.}$$

For the next 7.5^m, the motion was small.

„ „ 10.0^m, there was a max. group :—

$$z \dots 3^h 50.0^m, \quad 2a = 1.2 \text{ mm.}$$

Thereafter the motion became much smaller. At 4^h 36.6^m, however, there appeared a slight but distinct group, consisting of 2 maxima : 2a = 0.7 mm. These lasted about 6^m, the subsequent motion being very small and doubtful.

75. Christchurch, New Zealand. Magnetic Observatory.
(Observer, Henry F. Skey, B. Sc.)

Time of Commencement = 1^h 10.0^m. Total Duration = 3½^h

The diagram, which is very distinct, is on the whole similar to that obtained at Wellington. The successive maxima were as follows.

Maximum.	Time of Occurrence.	2a.	Maximum.	Time of Occurrence.	2a.
<i>a</i>	1 ^h 17.5 ^m	1.7 ^{mm}	<i>g</i>	2 ^h 5.5 ^m	9.6 ^{mm}
<i>b</i>	1 23.6	2.0	<i>h</i>	2 8.0	17.0
<i>c</i>	1 25.9	3.9	<i>i</i>	2 13.0	14.2
<i>d</i>	1 30.1	5.0	<i>j</i>	2 17.4	9.5
<i>e</i>	1 44.5	3.0	<i>k</i>	2 20.0	16.4
<i>f</i>	2 2.4	14.0	<i>l</i>	2 24.2	9.0

Maximum.	Time of Occurrence.	2 <i>a</i> .	Maximum.	Time of Occurrence.	2 <i>a</i> .
<i>m</i>	2 ^h 26.3 ^m	10.0 ^{mm}	<i>t</i>	2 ^h 45.7 ^m	2.9 ^{mm}
<i>n</i>	2 28.9	5.4	<i>u</i>	3 4.4	1.3
<i>o</i>	2 30.4	6.3	<i>v</i>	3 8.3	3.9
<i>p</i>	2 32.6	5.0	<i>w</i>	3 15.1	2.1
<i>q</i>	2 34.7	2.1	<i>x</i>	3 22.2	1.7
<i>r</i>	2 35.8	3.2	<i>y</i>	3 53.1	1.2
<i>s</i>	2 38.8	6.1	<i>z</i>	4 11.2	0.9

Notes to the above table:—

Between the commencement of the earthquake and (*a*), the motion was extremely small.

Between (*a*) and (*d*), both inclusive, there were 6 maximum groups, very nearly equidistant, the average interval being 2.5^m.

For some interval after (*e*), $T=28.0$ sec.

Other measurements of the period were as follows:—

$$\left\{ \begin{array}{l} \text{Between } (f) \text{ and } (h): T=18.0 \text{ sec.} \\ \text{,, } (h) \text{ and } (k): \text{,,} =16.3 \text{ ,,} \\ (s) \text{: ,,} =15.5 \text{ ,,} \end{array} \right.$$

The last three determinations give the average value of 16.6 sec., which must be the oscillation period of the pendulum. The period of 28 sec., for (*e*), was probably that of the earthquake motion at that particular epoch.

76. Mauritius. Royal Alfred Observatory. (Director, T. F. Claxton, F.R.A.S. Assistant Director, A. Walter.)

The seismograph had two components, EW and NS, the sensibilities to tilting being as follows:—

$$\left\{ \begin{array}{l} \text{NS Component: } 1 \text{ mm} = 0.29; \\ \text{EW } \quad \quad \quad : 1 \text{ mm} = 0.26 \end{array} \right.$$

Time of Commencement = $0^{\text{h}} 58^{\text{m}} 54^{\text{s}}$. Total Duration = 2^{h} .

1st Preliminary Tremor. The motion was very small, the duration being as follows:—

$$\left\{ \begin{array}{l} \text{NS} \dots\dots 8.0^{\text{m}}; \text{ EW} \dots\dots 8.3^{\text{m}}. \\ \text{Mean duration} = 8^{\text{m}} 9^{\text{s}}. \end{array} \right.$$

2nd Preliminary Tremor. The duration was as follows:—

$$\left\{ \begin{array}{l} \text{NS} \dots\dots 9.4^{\text{m}}; \text{ EW} \dots\dots 8.6^{\text{m}}. \\ \text{Mean duration} = 8^{\text{m}} 59^{\text{s}}. \end{array} \right.$$

Then there took place, in the NS component, a displacement of the pendulum towards the north; the EW pendulum remained in position. The subsequent record is very obscure; the motion becoming small after $5^{\text{h}} 52^{\text{m}}$.

77. Cape of Good Hope. (Pl. XXI, the *Publications*, No. 23.)

Royal Observatory (Director, Sir David Gill, K. C. B., F. R. S.)

Time of Commencement = $1^{\text{h}} 2.5^{\text{m}}$. Total Duration = $2^{\text{h}} 6^{\text{m}}$.

The commencement was not quite distinct.

1st Preliminary Tremor. Duration = $9^{\text{m}} 57^{\text{s}}$.

2nd Preliminary Tremor began with a max. group ($2 = 4.0$ mm), and remained for the next 23.3^{m} smaller than 1.5 mm. Then, at $1^{\text{h}} 36.2^{\text{m}}$, the motion became most active (max. $2a = 5.2$ mm), continuing so for 21.8^{m} .

Thereafter the motion became smaller, remaining nearly constant for the next 24.3^{m} (max. $2a = 2.0$ mm). The subsequent motion gradually diminished; very slight but distinct movement being indicated for further 30^{m} .

W_2 . What may correspond to the W_2 motion, consisting of a very slight maximum, appeared at $3^{\text{h}} 8.3^{\text{m}}$,

78. Toronto, Ontario, Canada. (Pl. XXII, the *Publications*, No. 23.) Met. Observatory (Director, R. F. Stupart, F. R. S. C).

Time of Commencement= $1^h 6.6^m$. Total duration= $3^h 33^m$.

The diagram is not very distinct.

1st Preliminary Tremor. During the first 7.6^m , the motion was very slight and doubtful. The first maximum group occurred at $1^h 14.2^m$, the $2a$ being 1.2 mm, and lasting for 3.9^m .

For the next 8.8^m , the motion was very small.

.. .. 22.7^m , .. was larger ($2a=1.8$ mm).

Then, at $1^h 49.7^m$, there began the most active portion, which lasted 20.4^m ; max. $2a=6.6$ mm.

For the next 38.5^m , the motion was smaller but more or less active, thence gradually decreasing.

79. Victoria, B.C., Canada. (Pl. XXII, the *Publications*, No. 23.) Meteorological Observatory (Superintendent, E. Baynes Reid).

Time of Commencement= $1^h 6.8^m$. Total duration= $3^h 33^m$.

For the first 37.0^m , the motion was small:— $2a=2.0$ mm.

For the next 11.3^m , the motion was most active:— $2a=12.4$ mm.

For the next 22.6^m , the motion remained nearly constant:— $2a=2.8$ mm.

The motion then gradually diminished.

The diagrams at Toronto and Victoria are similar in the earlier part of the motion.

80. Baltimore, Md., U.S.A. (Prof. Harry Fielding Reid.)

Time of Commencement= $1^h 10^m 30^s$. Total Duration= $3^h 40^m$.

The commencement is very indistinct, the indication becoming definite first at $1^h 15^m 48^s$,

The total duration of the 1st and 2nd preliminary tremors = $42^m 36^s$ (?); $2a=2.0$ mm.

The most active part began at $1^h 53^m 6^s$ and remained nearly constant for $20^m 24^s$, there being 6 maximum groups, the largest of which ($2a=6.0$ mm) occurred at $2^h 10^m$.

The subsequent motion was much smaller (max. $2a=2.5$ mm) and remained on the whole nearly constant for the next $15^m 30^s$; there being 4 max. groups occurring at an average interval of $5^m 10^s$. These 4 groups comprised altogether 64 complete (pendulum) oscillations, giving an average period of 15.2 sec. Thence the motion became again much smaller.

The duration of the principal portion was about 49^m .

The end of motion was at about $4^h 50^m$.

W_2 . What may correspond to the W_2 motion occurred at about $3^h 13^m 30^s$; $2a=0.8$ mm.

81. Calcutta, India. (Pl. XX, the *Publications*, No. 23).

Alipore Observatory. (Director, G. W. Kuchler, Assistant Meteorological Reporter).

The motion began very gradually, the duration of the preliminary tremor being about $3^m 9^s$. For the next $15^m 18^s$, the motion was very active and the boom end swang through the whole width of the photographic paper. For the next $13^m 24^s$, the motion was still active, but consisted in 5 max. groups. Then the motion gradually diminished till about $8^h 38^m$ (Calcutta time). Thereafter it remained very small.

W_2 began at $9^h 37^m$ (Calcutta Time), or at $2^h 56^m$ after the commencement of the earthquake. For the 1st 13^m , the motion was small and doubtful. For the next $16^m 30^s$, it was well defined, the last group having a max. $2a$ of 1.8 mm. After 4^m ,

during which the motion was small, there took place a small max. group ($2a=1.0$ mm), lasting 4.6^m . This latter may correspond to W_3 .

82. Kodaikânal, Madras, India.

Solar Physics Observatory. (Director, C. Michie Smith.)

The instrument had evidently a great friction, and the record is not satisfactory.

Commencement= $6^h 16.3^m$ (Madras Time), or $0^h 55.6^m$ (G.M.T.)

Total Duration= $3^h 36^m$.

The *1st Preliminary Tremor* lasted $3^m 55^s$, the max. $2a$ being 1.8 mm. For the next $2^m 19^s$ there were two max. groups, the first having the max. $2a$ of 22.6 mm. Then the index strack sideways and the record was not given till $8^h 13^m$ (Madras time), when the pointer was brought back by hand and put into the working condition again. The motion was distinctly shown till $8^h 33.2^m$ (Madras time), the max. $2a$ during this interval being about 1 mm. Thereafter the motion became very slight, and for the next 58.5^m , there was no very great variation, showing a series of very small max. groups.

A small maximum group, similar in form to that in the Liverpool and Edinburgh diagrams, occurred at $8^h 57.7^m$ (Madras time). This may correspond to W_2 , but the record is doubtful and the above may be a time signal.

83. Colaba, Bombay. (Pl. XX, the *Publications*, No. 23.)

Government Observatory. (Director, N.A.F. Moos.)

Commencement= $0^h 52.9^m$. Total Duration= $4^h 19.6^m$.

The diagram is on the whole similar to the Alipore one.

After the preliminary tremor, which lasted $3^m 31^s$, the motion became

suddenly large and continued very active for 8^m 42^s. During the next 9^m 42^s, it consisted of a number of separate maximum groups. Thereafter the motion gradually diminished.

The identification of W_2 and W_3 is doubtful.

84. *Honolulu*, T.H.* (Observer, S.A. Deel. Compiler, A.E. Burbank.)

Commencement.....	1 ^h 04. ^m 6
2nd Group	1 08. 7
Long Waves.....	1 15. 0
	{ 1 35. 2 (2.5 mm)
Maximum	{ 1 47. 2 (4.5 ,,)
	{ 1 55. 5 (8.2 ,,)
End	5 20. 0

Chapter IV. Velocity of Propagation of the 1st Preliminary Tremor.

85. *Places situated approximately on Same Great Circles of the Earth passing through the Origin of the Earthquake.*

The origin of the earthquake under consideration is situated among the great Himalayan mountain range, in the middle of the extensive continent of Asia. A question which naturally presents itself in connection with the transit velocity is whether or not the latter differed along the various routs of radial propagation. With a view of finding out such a relation, if possible, I have divided the different observing stations into a number of groups, as follows.

Group 1. Tacubaya, Toronto, Victoria, B.C., Colaba, (Bombay),

* Reproduced from Professor Milne's Circular, No. 13.