

ON 337 EARTHQUAKES OBSERVED DURING  
TWO YEARS IN NORTH JAPAN.

*October 1881—October 1883.*

by

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[Read April 21st 1884.]

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## I. INTRODUCTION.

The following paper is an account of 387 earthquakes observed in North Japan between October 1881 and October 1883. The area of observation lies between  $35^{\circ}$  and  $44^{\circ}$  North Latitude. It is shown in any one of the maps illustrating areas which have been shaken.

The shaded portions of these maps indicate mountainous districts, embracing hills from 500 to 1000 feet in height, and peaks, which in the central parts of the country attain heights of from 6,000 to 10,000 feet.

The coloured portions of these maps indicate areas which have been shaken by different earthquakes. Some disturbances have been so small that they were only observed at one town. Other have been sufficiently great to be felt almost over the whole area shewn in the map.

The maps are arranged in groups. Those maps which represent Earthquakes which have shaken neighbouring or approximately the same districts being placed near to each other.

The extent of country over which an earthquake was felt was determined as follows. First I distributed bundles of post cards to the government offices in all the important towns within a distance of 100 miles of Tokio, with a request that every week one of the cards should be posted with a note of any earthquakes which might have occurred. In consequence of the kindness of the officials at these offices, whom I now take the opportunity to thank, I soon discovered that almost every disturbance came to Tokio from the North and passed that city to the South and West until it reached the Hakone Mountains where it was suddenly stopped, as was indicated by the fact that those who resided in towns beyond these mountains had not noticed an earthquake to have occurred.

This fact having been established the barricade of post cards was extended towards the North, until finally I had

observers at all the places indicated in the following list.

On the map with the exception of Yokohama and Tokio each station is simply indicated by its number.

# LIST OF STATIONS.

Number.	Place.	Number.	Place.
T	Tokio	23	Numatsu
Y	Yokohama	24	Shidzuoka
1	Hojo	25	Tateyama
2	Otake	26	Taira
3	Mohara	27	Nakamura
4	Sakura	28	Wakamatsu
5	Choshi	29	Nihonmatsu
6	Narita	30	Yonezawa
7	Sakai	31	Yamagata
8	Asaw	32	Sendai
9	Mito	33	Kesen
10	Shimoda	34	Ichinoseki
11	Utsunomiya	35	Morioka
12	Ashikaga	36	Miyako
13	Takasaki	37	Komoro
14	Numata	38	Ida
15	Hachioji	39	Kamaishi
16	Fuchiu	40	Funai
17	Kofu	41	Hakodate
18	Nakanomura	42	Sapporo
19	Shimoda	43	Akishi
20	Yokosuka	44	Nemuro
21	Odawara	45	Niigata
22	Hakone		

Correspondence was occasionally received from many other places.

When an earthquake was recorded at only one of the stations it was assumed that the disturbance was quite local. Generally speaking the records of a given earthquake came from a group of places lying near each other. It has often

happened that a number of places have recorded an earthquake, whilst from two or three places in the midst of the same area no records have been received. In such a case it is assumed that these omissions have been accidental, the earthquake not having been felt; perhaps on account of its feebleness, perhaps because it occurred when the observer was out of doors, or in the middle of the night when he was asleep.

As a rule the areas on which earthquakes have been felt are along the eastern side of the country, the western extension of the disturbances being limited by heavy mountain ranges.

The most remarkable observations are those from two or more *groups* of places distant from each other, each group of places reporting an earthquake as having occurred at the same time.

These time observations are in the majority of cases only approximate, and if two towns report an earthquake on the same day and at a time not differing by more than 30 minutes, especially when the observation is made at night, I have assumed that the records refer to the same shock.

The only places at which good time observations have been made are the following—Tokio, Yokohama, Chiba, Kumagai and Kamaishi.

At the first two of these places the records were made by good clocks from which the time was taken automatically. These observations were often checked by several observers. The clocks at all the places were generally compared several times per week by a telegraphic signal which is sent throughout the country every day at 12 o'clock. For the use of this signal my thanks are due to Mr. T. Ishie the Director of the Imperial Telegraphs of this country.

At Hakodate and Saporu the time was obtained by comparison with chronometers at the observatories at these places. For these observations I have to thank Mr. N. Fukushi, Director of the Survey Department in Saporu, and his assistants in Hakodate.

All these times have been reduced to Tokio mean time.

From the area over which a shock was felt, the intensity of it at different points, the manner in which previous and

subsequent disturbances have occurred in the same area, the time at which the shock was recorded at different stations, and from these and the directions indicated by instruments, origins have been determined for nearly all the earthquakes to which reference is made.

It is needless to remark that these origins are only approximate, and although for convenience these origins are referred to as points, it is probable that many shocks may have originated from fissures of considerable extent.

In all cases details of calculation are omitted.

When obtaining an origin by time observations the method employed has usually been either that of Hyperbolas or that of Circles. (See Trans. Seis. Soc. Vol. II p. 69 and Vol. III, p. 132).

The instruments used were of many types, including the majority of instruments referred to in the Transactions of the Seismological Society.

The simplest are series of columns which are overthrown by severe shocks. Another instrument which I have largely used is a *dead beat* pendulum with a multiplying index writing its record on a stationary plate of smoked glass. Instruments of this type I have had in Tokio, Yokohama, Chiba, Kisaradzu, Kamaishi and Sapporo. I have placed similar instruments in other parts of Japan but these records are not referred to in this paper. A large number of these static records like Figs. 2, 3, 4 &c. have been reproduced by tracings made from photographs.

Another set of records are those drawn by various forms of bracket seismographs, conical pendulums and rolling sphere seismographs. These records were made on smoked paper or glass, the record receiving surface being either continuously in motion or only set in motion at the time of the earthquake.

These instrument are all designed to give with but slight error a diagram of the actual movement of the earth, with regard to its amplitude, its period of vibration, and its direction.

Inasmuch as it will be observed that different instruments give different results for the same earthquake, in order

that the reader may not regard such diagrams as conflicting, the following results, which have been obtained from the earthquakes here referred to and which have been confirmed by many observations made subsequently, may be enumerated.

1. An ordinary earthquake, although having a general direction of propagation, has at a given point many directions of vibration. If there is a decided shock in a disturbance this particular movement may be indicated in the same manner at adjacent stations.

2. The amplitude of motion as observed at two adjacent stations even if only a few hundred feet apart may be extremely different.

3. The period of motion may vary like the amplitude, the instruments being in all cases as similar as it is possible to construct them.

At present I am carrying on observations by means of three similar instruments placed at the corners of a triangle the sides of which are about 800 feet in length. When these instruments are side by side they practically give *similar* diagrams. At their present positions they always give *different* diagrams. If these instruments were in the hands of distinct observers each of these observers would give a totally different account of the same earthquake. Judging from the quick period and large amplitude of motion always observed at one particular corner of my triangle, I can say with confidence that at this corner there might be sufficient motion to shatter a building, whilst at the other corners, similar buildings would not be damaged.

Other results which have been obtained will be enumerated subsequently.

A description of many of the instruments by which these results have been obtained will be found in the pages of the Transactions of the Seismological Society. A description of the principal instruments which I have used together with a comparison of their relative merits will be found in Vol. IV. of the above mentioned Transactions p. 85. &c.

In Tokio the places of observation were as follows.

1. *Yamato Yashiki* (Imperial Meteorological Observatory.)

At this place, which is situated at the foot of a steep slope rising from the Tokio plain, there was for many years one of Palmieris' instruments. About November 5th 1882 this observatory was moved to a point about 1 mile distant, in the center of Tokio near the grounds of the castle.

In the Yamato Yashiki records quoted in this paper the intensity in different directions is indicated by degrees and minutes. Thus WNW 30' means that mercury contained in the WNW tube was caused to oscillate until an index connected with a float on the mercury had turned through 30 minutes of arc.

2. *Yama Guchi Yashiki*. Until 1882 this was my private residence. Here a variety of instruments were in use. The situation is about half way up the slope at the foot of which the Yamato Yashiki observatory was situated.

It was at this place that most of the diagrams given in this paper were obtained. One common characteristic of them, is their smallness as compared with others taken in different localities. From more recent experiments I now know that had I moved my observatory about 100 yds distant down to the flat ground, the amplitude of motion indicated in the above diagrams would at least have been doubled. A series of diagrams obtained with the same instruments installed on the flat ground, I hope to publish in a subsequent paper.

3. *Kobu Dai Gakko*. (Imperial College of Engineering) This place is about a quarter of a mile distant from the two former places. It is situated on tolerably level ground raised almost 30 feet above the flat ground on which the greater portion of the city is built.

4. *Dai Gaku*. (University).

This is situated on the flat plain of Tokio, about two miles distant from the former places.

It was here that Prof. Ewing's instruments were observed. This is a good locality for obtaining records. At this place large amplitudes of motion have been noted whilst at other parts of Tokio the same earthquake has been passed by unnoticed.

In Yokohama I was greatly assisted in my observations by Merss. Talbot, Bisset, Pryer and Owston. The former of these gentleman built a special observatory in which a variety of instruments gave a series of valuable records. Nearly all the observations in Yokohama were made on a plateau 100 feet above sea level bounded by steep bluffs.

In interpreting many of the records which have been obtained, it must be pointed out that much assistance has been obtained from records which had been obtained previously and also subsequently to the years which are particularly referred to in this paper.

Examples of the earliest observations which were made commencing in 1876 have already been laid before this society.

In a Memoir of the Science Department of the Tōkiō Daigaku published in 1883 on Earthquake Measurements the author, Prof. J. A. Ewing, remarks that so far as he "is aware no continuous record of earthquake motion had been previously obtained"—that is prior to his own observations in November 1880.

The first continuous records which I obtained, which were published in the Transaction of the Seismological Society, were made at the end of 1879. These however only represented a small portion of the earthquake not lasting over more than six seconds. They were however sufficient to enable me to state, that earthquake motion was irregular, that its amplitude was only a few millimeters, and that there were only 2 or 3 vibrations per second. Prof. Ewing's records which succeeded these were certainly more complete, inasmuch as the earth's motion was magnified and the period over which a record was drawn was considerably increased.

About this time continuous records were also obtained by Father Faura of Manila.

The horizontal lever seismographs which have played such an important part in Seismology were first used by Prof. W. S. Chaplin. A similar instrument was subsequently but independently constructed by Mr. T. Gray. Neither of these gentlemen so far as I am aware obtained any records. Still later, in Nov. 1880, the instrument was again reproduced



but in an improved form. The friction of its parts had been reduced, a multiplying index had been added and the principle of its action enunciated. It was with this instrument, the successful working of which is due to Prof. Ewing, that good results were first obtained.

For great assistance in working up the numerous records which I have received, my best thanks are due to Messrs. Kuwabara and Matoba of the Kobudaigakko, without whose help I should have experienced great difficulty.

## II. CATALOGUE OF EARTHQUAKES.

In the following catalogue the various earthquakes which have been recorded succeed each other chronologically, and are numbered consecutively.

- |               |  |
|---------------|--|
|               | — 1 —                                  |
| 1881. Oct. 2. | Hakodate 9.30                          |
|               | — 2 —                                  |
| Oct. 19.      | At <b>3.</b> 11.30 A. M. feeble. N. W. |
|               | — 3 —                                  |
| Oct. 19.      | At Hakodate 9.28 P. M.                 |
|               | — 4 —                                  |
| Oct. 21.      | At <b>8.</b> 2 A. M. feeble. S. W.     |
|               | — 5 —                                  |
| Oct. 22.      | At Sapporo 6.20 A. M.                  |
|               | — 6 —                                  |
| Oct. 24.      | At Hakodate 2.57 P. M.                 |

## —7. Map 1.—

1881 October 25th 9.24.15 P. M.

This shock was felt all over the eastern part of north Japan, being strong in the north at Hakodate and Sapporo and comparatively weak in the south near Tokio.

**TOKIO.** *Yama Guchi Yashiki.* The shock was short and gentle. A lamp swung NW. SE. A pendulum seismograph (Fig. 2) gave a clear record of motion, first N  $5^{\circ}$  E to S  $5^{\circ}$  W. and subsequently E and W. The maximum amplitude of the first displacement was 1.9<sup>mm</sup> and of the second 1.3<sup>mm</sup>.

A pair of conical pendulums (Fig. 1) indicated a motion extending over at least 45 seconds. The components were N  $17^{\circ}$  E and E  $23^{\circ}$  S. The former of these was the larger. The period of the vibrations at the commencement of the disturbance was .46 sec. After 20 seconds of motion the period became almost 2.5 seconds.

A bracket ring seismograph (Fig. 5) indicated a slight movement E  $23^{\circ}$  S. The period was about .3 sec. The portion of the instrument recording motion N  $23^{\circ}$  E was not in working order.

A double bracket seismograph (Fig. 6) indicated a slight motion commencing with a period of about .3 sec and dying out with slow waves. There was no vertical motion.

As the record given by these two last mentioned instruments was so extremely small, only 6 seconds of the disturbance has been shown in the Figures.

The time at which the disturbance commenced was 9.24.22 P. M.

*Kobu-Dai-Gakko.* Out of a set of columns, only one small inverted cone fell. It stood on a platform with a spherical base.

*Yamato Yashiki Observatory.* Time 9.24.15. Directions NNE and NNW  $10'$ , WNW  $30'$ . Duration 1<sup>m</sup>.30<sup>s</sup>.

**YOKOHAMA.** Time (Talbot) 9.24.45 P. M.

(Owsten) 9.24.42

The mean of the above is 9.24.43

A pendulum seismograph (Fig 4) indicated the principal motion N 20 E with an amplitude of 9<sup>mm</sup>. There were also movements transverse to this.

The shock is described as having been sudden. It was followed by gentle tremors.

CHIBA. Pendulum seismograph. (Fig. 3). Direction. N 62 E with smaller transverse motions slightly E of N and W of South. The former had a maximum amplitude of .8<sup>mm</sup> and the latter .1<sup>mm</sup>. It is doubtful if the latter is an earthquake indication.

HAKODATE or **41**. Time 9.22.14. The motion was violent. Direction ENE, WSW and N & S. A second shock was felt a few minutes later.

SAPORO or **42**. Time 9.22.32. Chief motion NE. SW. The amplitude of motion as indicated by a pendulum seismograph (Fig 7) may have reached 7<sup>mm</sup>. The shock is said to have been severe. The duration was over a minute. It commenced as a series of tremors in a direction N 17 E, followed by a lurch N 28 E, when the pointer was thrown off the plate on which it was intended to write its record.

Records from other places were as follows:—

At **4**. 10.10 P. M. feeble—**7**. 10.20 feeble SW—**8**. 10.10 P. M. pretty strong—**10**. 9.55 P. M. pretty strong E.—**11**. 9.50 P. M. feeble SE—**12**. 10.5 P. M.—**13**. 10.0 P. M. feeble SW—**20**. 9.35 P. M. feeble.—**44**. severe.

#### *Origin of the Shock.*

From the severity of the shock at Hakodate and Sapporo as compared with the slight motion experienced in the south, together with a consideration of the places where the disturbance was observed, it might be inferred that the origin was beneath the ocean eastwards from Hakodate. It might also be argued that this origin was nearer to Hakodate than Sapporo, the disturbance having been more severe at the former of these places.

From the directions given by seismographs at Tokio, Chiba and Yokohama, in conjunction with the principal direction indicated by the seismograph at Sapporo, it would appear that the origin might either be near the Volcano of Kumagatake

on the shore of Volcano Bay in  $140^{\circ}.20'$  E. Long. and  $42^{\circ}.10'$  N. Lat, or in  $142^{\circ}.20'$  E. Long. and  $41^{\circ}.40'$  N. Lat. Using a time hyperbola between Hakodate and Saporu in conjunction with a direction given by the Saporu instrument, we should conclude that the origin was farther to the eastward, in about  $142^{\circ}$  E. Long. and  $42^{\circ}$  N. Lat.

Working with the aid of the time data alone, either by the method of circles or that of hyperbolas, the origin is thrown still farther to the east to about  $144^{\circ} 15'$  E. Long. and  $41^{\circ}$  N. Lat.

These three possible origins all lie on an ESE line about 150 miles long, drawn from the head of Volcano Bay.

Of these origins the second is the one most probably correct. The second and third origin it may be observed lie on the flanks of the continuation of a great anticlinal crossing Yezo in a NW SE direction. This is indicated on map 124 by a dotted line.

#### *Velocity of Propagation.*

Assuming the time observations to be correct the disturbance, which must have passed between Tokio and Yokohama in what was practically a straight line, did so at a rate of over 4500 feet per second. Assuming the origin to have been near the head of Volcano Bay the shock must have travelled from the Hakodate homoseist on to Saporu at a rate of more than 8600 feet per second.

With other assumptions as to the origin, we obtain different velocities along different lines, some of which are as much as 10,000 feet per second.

The general conclusions are that the velocities of propagation are different along different lines, being greatest between points which are near the origin. The variations in velocity lie between 9000 and 4000 feet per second.

These calculations are based on the assumption that the shock first reached Hakodate and that it was felt 18 sec later at Saporu, 128 sec later at Tokio and 149 sec later at Yokohama.

It must be observed that if the direction observations were neglected and it was assumed that the various time observa-

tions were correct, and also that the earthquake travelled in all directions with the same velocity as it travelled between Tokio and Yokohama, a fourth possible origin might have been calculated.

— 8 —

1881. Nov. 5.

**25.** 1.04 A. M. feeble. W.

— 9 —

Nov. 10.

**25.** 6.15 A. M. feeble.

— 10 (Map 111) —

Nov. 11 9.10.56.

TOKIO. *Yamato Yashiki*. Time 9.10.56 and 9.11.21 A. M.  
Direction NNW 40', ENE 30', ESE 30'.

CHIBA. Time 9.11.0 Pendulum seismograph (Fig. 8) indicated a single motion of 1<sup>mm</sup> N 60° E and a series of motions of about .1<sup>mm</sup> N 20 E.

Other places where the shock was felt were:—

At **2.** 10.9 A. M. feeble—**6.** 9.25 A. M.—**12.** 9.50 P. M.  
**39.** 9.10 A. M.

*Origin.* From the distribution of places at which the disturbance was felt, and the indicated directions, it is probable that the shock originated beneath the ocean about 400 miles NNE of Tokio or in the same locality as Number 7.

— 11 —

Nov. 11.

At **2.** 11.24 P. M.

— 12 —

Nov. 12.

At **39.** 3.30 A. M.

— 13 —

Nov. 15.

**12.** 3.10 A. M. feeble.

— 14 (Map 39) —

Nov. 15. 9.47.32 P. M.

**TOKIO.** *Yama Guchi.* A slight shock at 9.43.54 a pendulum seismograph (Fig. 9) indicated a maximum motion of .5<sup>mm</sup> in a direction N 8° E. A double bracket seismograph (Fig. 11) showed 3.5 vibrations per second. These are too much drawn out by the rapid motion of the plate to indicate direction. A pair of heavy ring bracket seismographs indicated an extremely slight motion.

There was no vertical motion.

A pair of conical pendulums indicated a very slight motion extending over about 25 sec. The first 10 seconds of this are shown in (Fig. 10). There were about 3.5 vibrations per second.

*Yamato Yashiki.* 9.47.32 P. M.

*Yokohama.* Mr. Owston observed at 9.43.23 P. M.

A pendulum instrument writing on a moving plate gave very slight ripples in a NS direction having an amplitude of about .1<sup>mm</sup>.

The shock was also felt at;—

**2.** 10.23 P. M. duration 5<sup>s</sup>. **11.17** P. M. duration 7<sup>s</sup> both shocks being feeble.—**4.** 9.50 P. M.—**6.** 9.45 P. M. and 9.50 P. M.—**7.** 11.10 P. M. feeble SW.—**8.** 10.4 P. M. 10.9 P. M. and 11.0 P. M. The first two shocks SE and the last SW.—**9.** 10.5 P. M.—**10.** 10.15 P. M., feeble; 10.20, feeble; 11.20, pretty strong, and 11.22, feeble.—**11.** 10.43 P. M. strong, SE.—**2.** 10.20 P. M., strong.—**14.** 10.15 P. M.—**18.** 11.0 P. M. feeble—**46.** 10.20 P. M.

*Origin.* From the directions indicated by seismographs we should look towards the North for the origin of this disturbance. The fact that 4 shocks were felt at **10**, and 3 shocks at **8**, also point to an origin North from Tokio. At both **2** and **6** no shocks were felt. If we draw a NW SE line from between **10** and **12**, through **8**, **6**, **3**, down to **2** and then refer to the earthquakes before and after the one under discussion, we see that this was a line along which there was activity for several days. The greatest amount of activity being in the south near **4**, **6** and **3**. The line it may be observed approximately follows the valley of the Tonegawa. The probability is that

this series of earthquakes had their origin in the continuation of this line beneath the sea.

1881. Nov. 16. — 15 —

**6.** 4.5 A. M.

Nov. 16. — 16 —

**6.** 8.10 A. M.

Nov. 18. — 17 —

**4.** 4.30 P. M. feeble.

Nov. 19. — 18 (Map 75) —

**4.** 8.50 P. M.?—**8.** 9.55 P. M. SW.—**9.**  
8.50 P. M.

Nov. 23. — 19 —

**46.** At night.

Nov. 24. — 20 —

**2.** 8.26 P. M. very feeble, duration 4"

Nov. 26. — 21 —

*Kiseradzu* At 9.30 P. M. A pendulum seismograph showed a NS motion of 3<sup>mm</sup>. (Fig. 13). The earthquake is doubtful.

Nov. 27. — 22 —

**25.** 7.20 P. M, feeble, N. S.

Nov. 29. — 23 (Map 82) —

**5.** 11.28 A. M. feeble—**6.** 11.0 A. M.  
feeble.

— 24 —

1881. Dec. 3.

TOKIO. 9.16.43 A. M.

— 25 —

Dec. 3.

**2.** 11.25 P. M. very feeble.

— 26 (Map 53) —

Dec. 5.

**17.** 1.28 P.M.—**22.** 1.15 P.M. two feeble shocks from the west.—**38.** 1.26 P.M.

— 27 —

Dec. 5.

**40.** 1.30 P. M. (This may have been simultaneous with earthquake 26.

— 28 —

Dec. 8.

**34.** 1.10 P. M. SE.

— 29 —

Dec. 8.

**7.** 10.0 P. M., feeble, NW.

— 30 (Map 32) —

Dec. 9.

**4.** 8.5 P. M. feeble.—**6.** 8.0 P. M.—**7.** 10.0 P. M. NW—**8.** 9.30 P. M.—**9.** 9.0 and 9.1 P. M.—**10.** 9.5 and 9.10 P. M., both feeble—**12.** 9.25 P. M. very feeble.—**26.** 9.40 P. M. feeble—**39.** 10.10 P. M.

— 31 (Map 13) —

Dec. 10.

**34.** 10.40 P. M.—**39.** 10.42.30 P. M. duration 2<sup>s</sup>. NE and N moderate.

— 32 (Map 79) —

Dec. 11.

TOKIO. 11.5.14.

YOKOHAMA. A pendulum seismograph showed an E. W. motion of 1.5<sup>mm</sup> (Fig. 14).



— 33 —

1881. Dec. 15.

**34.** 8.25 P. M. SW.

— 34 —

Dec. 18.

**26.** 4.50 A. M. very slight.

— 35 (Map 74) —

Dec. 19.

**7.** 9.0 P. M., feeble SE.—**10.** 8.25 P. M., feeble—**12.** 8.45 P. M. feeble.

— 36 —

Dec. 22.

**12.** 1.50 A. M. feeble.

— 37 (Map 72) —

Dec. 22.

**6.** 11.45 P. M.—**10.** 11.40 P. M. feeble.

— 38 (Map 45) —

Dec. 23. 4.40.10 A. M.

TOKIO. *Yama Guchi.* Time 4.37.6 as observed by watch and 4.37.54 as observed by a clock which was stopped.

A pendulum seismograph did not show any motion.

A pair of conical pendulums (Fig. 15) writing on a revolving drum gave the following record. Motion in a direction N 17 E commenced gently, reached a maximum in two or three seconds and practically died out in about 12 seconds. The motion at right angles to this N 73 W, commenced with three large vibrations and continued for fully 15 seconds. There appears to have been from 3 to 4 complete vibrations per second.

*Yamato Yashiki.* Time 4.40.10 A. M.

*Yokohama.* During the night three shocks were felt.

The largest gave with a pendulum seismograph a motion of about 2<sup>mm</sup> in an ENE WSW direction.

CHIBA. The disturbance which was short and severe commenced at 4.34.56 lasting 20 seconds.

A pendulum seismograph (Fig. 12) gave a decided motion

N 60 W with an amplitude of 1.5<sup>mm</sup>. There were also N and S transverse motions.

The earthquake was also felt at,—

**2.** 5.0 A.M. duration 60<sup>sec</sup>.—**4.** 4.35 A.M., feeble.—**6.** 4.30 A. M., strong.—**7.** 5.0 A. M. feeble, NE—**8.** 4.30 A. M.—**9.** 3.50 A. M.—**10.** 6.0 A. M. pretty strong.—**14.** 5.5 A. M.

*Origin.* It is probable that the origin of this shock was the same as that of Nov. 15 (No. 14).

— 39 —

1881. Dec. 24.

**6.** 5.40 P. M.

— 40 —

Dec. 25.

**12.** 10.5 A. M. pretty strong.

— 41 (Map 5) —

Dec. 25.

SAPORO. Time 2.40.0 P. M. (local). Direction ESE WNW. Intensity slight.

NEMURO. Time 2.47.0 P. M. (apparent). A strong shock from the SW.

The shock was also felt at,—

**39.** 3.0 P. M.

— 42 (Map 13) —

Dec. 25.

**39.** 10.0 P. M.—**34.** 10.05 P. M.

— 43 (Map 2) —

Dec. 26, 1.12.30 P. M.

TOKIO. *Yama Guchi.* Time 1.12.35 calculated from 12 o'clock gun fire. A short sharp push.

Conical pendulums (Fig. 16) writing on a drum started by the shock. The N 17° E motion consists of a few gentle ripples lasting about 8 seconds. The N 73 W motion can be traced for about 15 seconds. The movement is greater in this component than in the former. There were about 4.5 complete vibrations per second.

The diagrams given by a pair of rolling cylinder seismographs on a revolving plate indicated motion extending over about 20 sec. Six seconds of the N 20 W motion is given in (Fig. 17). It is similar to the N 110 W motion. There were from 4 to 4.5 vibrations per second.

*Yamato Yashiki.* Time 1.12.30 P. M. Directions SSE 40'. SSW, 20'. WNW, 10'.

*KAMAISHI.* Time 1.13.40 (Telegraph time). The shock which was moderate was accompanied by a rumbling sound. Duration 10<sup>sec</sup>. Direction about ENE.

This disturbance was also felt at,—

**9.** 1.30 P. M.—**10.** 1.30 P. M. strong—**13.** 1.30 P. M. feeble.—**14.** 1.30 P. M.—**17.** 1.0 P. M. feeble. **18.** 2.0 P. M. feeble—**26.** 1.20 P. M. strong. **27.** 2.0 P. M. strong—**28.** 1.30 P. M.—**29.** 2.50 P. M. pretty strong, W.—**30.** 2.25 P. M. N. W.—**31.** 2.0 P. M. pretty strong, N. E.—**32.** 1.44 P. M. pretty strong, duration one minute.—**34.** 1.23 P. M. S.—**39.** 1.13.40 P. M. duration 10', ENE, very moderate, a continuous rumbling heard.—**42.**

*Origin.* The origin of this shock is probably beneath the sea about 350 miles NE from Tokio. (see No. 7).

— 44 —

Dec. 28. 10.4.0 A. M.

*Hama Saki.* A sharp shock lasting about 15 seconds. Capt Carrew, who records this shock, remarks that it appeared to originate right under his vessel which was anchored in 5 fathoms of water.

— 45 —

Dec. 28.

**38.** 6.30 P. M., feeble.

— 46 (Map 101) —

Dec. 29.

Tokio 4.24.15 A. M. Directions WNW, 20'. SSE, 15'. Duration 25'—**14.** 4.20 A. M.

— 47 (Map 89) —

Dec. 29.

TOKIO 5.4.7 P.M. Directions WSW, 30'.SSW, 30'.SSE, 10'.

*Yama Guchi.* A long gentle earthquake. A double bracket seismograph gave a few ripples.

*Yokohama.* A pendulum seismograph (Fig. 18) appears to have given one swing East and West. Amplitude 1.7<sup>mm</sup>.

This earthquake was also felt at:—

**2.** 5.49 P. M. feeble, duration 1<sup>m</sup>. 20<sup>s</sup>.—**25.** 6.0 P. M. feeble, E.

— 48 —

1881. Dec. 31.

**25.** 10.05 A. M. feeble. N.

— 49 (Map 59) —

Dec. 31 12.24.15. P. M.

TOKIO. *Yama Guchi.* Time 12.19.50. P. M.

Conical pendulums (Fig. 19). N 17 E motion can be traced as slight ripples over a period of about 15 seconds. There appear to have been about 5 complete vibrations per second. N 73 W motion is the better defined.

A Pendulum seismograph (Fig. 20) indicated a decided motion of .8<sup>mm</sup> W 30 S. There were also transverse motions.

A vertical spring lever instrument (Fig. 21) indicated about 4 up and down movements per second.

*Yamato Yashiki.* Time 12.24.15 P. M.

YOKOHAMA. Mr. Talbot timed the shock at 12.27.56.

The motion was decided but not violent. A pair of brackets gave a clear diagram on a revolving plate.

A pendulum seismograph (Fig. 22) indicated motion in various directions, the North and South being the most prominent with an amplitude of 1<sup>mm</sup>.

A second similar instrument in another part of Yokohama indicated a principal motion NNW.

CHIBA. Time 12.24.30 Duration 10<sup>sec</sup>. Intensity slight. This earthquake was also felt at,—

**1.** 0.35 P.M. feeble—**15.** 0.40 P.M. SW, duration 5<sup>sec</sup>—**17.** 11.20 A.M.—**18.** 1.0 P.M. feeble—**20.** 0.26 P.M. feeble—**21.** 0.30 P.M.—**22.** 12.0 very feeble W—**23.** 0.55 P.M. feeble. SW.

— 50 —

1882. Jan. 2.

**14.** 3.0 A. M.

— 51 (Map 96) —

Jan. 2. 5.47.26 P. M.

TOKIO. *Yama Guchi*. The instruments at this place did not give the slightest record.

*Shiba*. The shock was felt by several persons. A few seconds before the motion a sound was heard.

*Yamato Yashiki*. Time 5.47.26 P. M. Directions NNW 30', WNW 20', ENE 10'. Duration 16".

This appears to have been a shock only felt in certain parts of Tokio.

This shock was also felt at **1.** 6.15 P. M.

— 52 —

Jan. 5.

**26.** 11.0 A. M. feeble.

— 53 (Map 75) —

Jan. 5.

**4.** 10.10 P. M. feeble—**8.** 10.30 P. M.—

**9.** 10.5 P. M.—**10.** 9.40. P. M. feeble,  
W.

— 54 —

Jan. 6.

**40.** 5.50 A. M.

— 55 (Map 10) —

Jan. 7.

**35.** 9.0 P. M. feeble, N—**36.** 9.45 P. M.  
feeble.—**39.** 10.30 P. M.

— 56 —

Jan. 9.

**29.** 2.0 A. M. feeble, W.

— 57 (Map 16) —

Jan. 9.

TOKIO. *Yama Guchi*. At 6.2.30 A. M. a distinct shaking was felt, lasting 60 seconds.

Whether this was the same shock that was felt at a large number of places in North Nipon is doubtful, inasmuch as intermediate places were not disturbed.

This shock was also felt at,—**26.** 6.20 A. M. feeble—**27.** 6.30 A. M. feeble. NNE—**32.** 6.25 A. M. feeble but long—**33.** 5.54 A. M., pretty strong but long—**34.** 6.20 A. M. SE.—**35.** 7.0 A. M. feeble. S—**39.** 5.20 A. M. duration 1<sup>m</sup>. NNE. moderate.

— 58 —

1882. Jan. 11.

**29.** 1.0 A. M. feeble, W.

— 59 —

Jan. 11.

**39.** Two shocks at 6.40 and 7.0 A. M.

— 60 —

Jan. 11.

**8.** 11.30 P. M.

— 61 (Map 38) —

Jan. 12. 12.0.55 P. M.

CHIBA. A slight shock lasting 10 seconds took place at 12.0.55 P. M.

This shock was also felt at,—

**4.** 1.0 A. M. feeble.—**7.** 1.0 A. M. feeble, N E—**14.** 1.0 A. M.—**26.** 1.0 A. M. feeble.—**29.** 1.0 A. M. strong, S.

— 62 (Map 65) —

Jan. 12.

**2.** 0.8 P. M. feeble, duration 7 sec.—**3.**

11.50 A. M. feeble.—**9.** 0.20 P. M.

— 63 (Map 30) —

Jan. 13.

**8.** 8.30 A. M.—**9.** 8.37 A. M.

— 64 (Map 105) —

Jan. 14. 7.34.15.

TOKIO. At Yama Guchi, Shiba and Shinagawa the shock does not appear to have been felt although numerous enquiries

were made. At the Kobu-dai-gakko, in Azabu, and at Komaba it was slight. In a club in Igura it was so severe that members were on the point of leaving the building.

*Yamato Yashiki.* 7.34.17. P. M. Directions WNW 10', WSW 10'.

YOKOHAMA. Time 7.34.17. P. M.

The motion as indicated by a pendulum seismograph (Fig. 20) was first N and S. This was followed by an E and W. movement the amplitude of which was about 1<sup>mm</sup>.

CHIBA. Time 7.35.7. Intensity was slight. Duration about 5 seconds.

The shock was also felt at:—**12.** 7.50 P. M. very feeble.

*Origin.* From the fact that the shock was felt in Yokohama at the same time that it was felt in Tokio, the origin ought to be on a line which bisects the line joining Tokio and Yokohama at right angles. Assuming the principal direction at Yokohama to have been E W, we obtain an origin on the east side of Yedo Bay near to a place at which several severe shocks have been known to originate. This origin would agree with one deduced from the area over which it is known the disturbance was felt. The data which do not agree with this determination are the directions observed in Tokio and the time observed at Chiba.

— 65 —

1882. Jan. 15.

NEMURO or **44.** 4.40 P. M.

— 66 —

Jan. 16.

NEMURO or **44.** 4.33 A. M. On this date there was a slight shock at 39.

— 67 —

Jan. 16.

NEMURO or **44.** 3.27 P. M. On this date there was a slight shock at 39.

— 68 —

Jan. 16.

KAMAISHI or **39.** A slight shock from the NNE.

1882. Jan. 18. — 69 —  
**34.** 1.15 P.M. E.
- Jan. 18. — 70 —  
**35.** 10.30 P. M. feeble.
- Jan. 19. — 71 (Map 31) —  
**9.** 6.40 A. M—**10.** 6.20 A. M. feeble.—  
**26.** 6.9 A. M.
- Jan. 21. — 72 —  
**10.** 3.40 A. M. feeble.
- Jan. 22. — 73 —  
NEMURO or **44.** 9.41 A. M.
- Jan. 22. — 74 —  
NEMURO or **44.** 11.36 A. M.
- Jan. 23. — 75 —  
**39.** 1.50 A. M. duration 3<sup>s</sup>, strong, NNE.
- Jan. 25. — 76 (Map 15) —  
**29.** 1.0 A. M. feeble, N S—**32.** 1.56  
A. M. feeble and short—**34.** 2 A.M. E.
- Jan. 25. — 77 —  
8.22.20 A.M.  
KAMAISHI or **39.** A. moderate NNE  
shock at 8.22.20 A. M.
- Jan. 25. — 78 (Map 109) —  
TOKIO. Yamato Yashiki. Time 3.47.27  
P. M. Duration 50 sec.



CHIBA. Time 3.47.41. The shock, which was slight, lasted 35 seconds.

This earthquake was also felt at—**2.** 3.0 P.M.—**4.** 3.36 P.M. feeble.—**5.** 3.30 P.M.—**8.** 4.15 P.M.—**9.** 3.50 P.M.—**10.** 4.10 P.M. feeble.—**13.** 3.50 P.M.—**26.** 4.30 P.M. feeble.—**29.** 3.40 P.M. feeble N W—**39.** 3.10 or 3.22.20 A.M.? Duration 13<sup>s</sup>. NNE moderate.

— 79 —

Jan. 25.

**10.** 8.30 P.M. feeble.

— 80 —

Jan. 25.

**26.** 11.20 P.M. very feeble.

— 81 (Map 12) —

Jan. 26.

**33.** 8.0 A.M.—**39.** 7.40

— 82 —

Jan. 28.

**12.** 1.5 A.M. pretty strong.

— 83 (Map 115) —

Jan. 28.

**14.** 11.50 P.M.—**26.** 12.0 P.M. very feeble.

— 84 (Map 40) —

Jan. 29.

TOKIO. 1.6.0 A.M.

**15.** 1.2 A.M. duration one minute.

— 85 (Map 119) —

Jan. 29.

TOKIO. *Yama Guchi.* Time 12.6.18  
A.M. a slight shock.

A pendulum seismograph (Fig. 24) indicated a motion of .4<sup>mm</sup> N 25 E.

*Yamato Yashiki.* Time. 12.6.0 A.M. Directions ENE, 1'.20". NNW, 30'. NNE, 20'. ESE, 10'. Duration 17<sup>s</sup>.

CHIBA. A very slight shock was felt at 12.3.23 A. M.

YAMAGATA. Here three shocks were felt. The first of these which was strong moved N and S.

— 86 —

1882. Jan. 29.

**10.** 11.40 P. M.

— 87 (Map 113) —

Jan. 29.

**33.** 12.40 P. M.—**34.** 11.20 P. M. SE.—

**38.** 10.40 P. M. feeble.

— 88 (Map 18) —

Jan. 30.

**9.** 3.45 A. M.—**26.** 3.24 A. M. feeble.—

**27.** 3.5 A. M. pretty strong, NE—

**28.** 3.0 A. M.—**29.** 4.0 A. M. strong—

**30.** 2.20 A. M. NW—**32.** 3.24 A. M. feeble but long—**39.** 2.30.

— 89 (Map 17) —

Jan. 31.

**26.** 5.30 P. M. very feeble.—**27.** 4.45

P. M. feeble E—**29.** 5.30 P. M. strong,

W—**32.** 3.25 and 5.25 P. M. both

feeble—**33.** 5.10 P. M. feeble—**34.**

5.20 P. M. S—**36.** 5.30 P. M.—**40.**

5.35 P. M.

— 90 —

Feb. 1.

TOKIO. Early in the morning a strong shock was felt at Surugadai. It was not felt at Yamato Yashiki nor at Yama Guchi.

— 91 (Map 19) —

Feb. 1.

**9.** 6.20 A. M.—**26.** 7.20 A. M. feeble—

**27.** 7.40 A. M. feeble, E—**29.** 4.0

A. M. feeble, S.—**32.** 7.50 A. M. feeble.

—**39.** 5.10.0 A. M. duration 3". NNE, strong. Pheasants screamed.

1882. Feb. 1. ——— 92 (Map 73) ———

**8.** 1.40 P. M.—**9.** 0.15 P. M.—**10.** 1.10  
P. M. pretty strong.

Feb. 3. ——— 93 ———

**26.** 5.30 A. M. very feeble.

Feb. 3. ——— 94 ———

NEMURO or **44.** 6.20 A. M.

Feb. 3. ——— 95 ———

**8.** 8.30. P. M.

Feb. 4. ——— 96 ———

NEMURO or **44.** 10.15 A. M.

Feb. 6. ——— 97 (Map 110) ———

TOKIO. *Yama Guchi.* Time 5.3.15 A. M.

A pendulum seismograph (Fig. 25) gave a slight motion  
.2<sup>mm</sup> N 10 E.

A rolling cylinder seismograph (Fig. 26) indicated motion  
of .15<sup>mm</sup> chiefly in an E W direction. The period was  
.33 sec. Duration 20 sec. Only 10 seconds of motion are  
shown in Figure. A Double Bracket on a moving plate  
(Fig. 27,) showed from 2.5 to 3.5 vibrations per second. Amplitude about. 2<sup>mm</sup>. The direction of motion was E 23 S. Only 4  
seconds of the record is shown. A pendulum seismograph  
writing on a moving plate gave the diagram shown in Fig.  
28. Owing to the slowness of the earth's motion there seems  
to have been a swing in the pendulum.

*Yamato Yashiki.* Time 5.0.30 A. M.? Directions NNW,  
10'. NNE 10'.

*Yokohama.* Time 5.3.38 A. M.

Other places at which this earthquake was felt, were;—**1.** 5.30 A. M. feeble.—**2.** 5.0 A. M. feeble, duration 9<sup>s</sup>.—**14.** 5.0 A. M.—**25.** 4.0 A. M. feeble, NW.—**26.** 5.10 A. M. feeble.—**24.** 3.50 A. M. feeble, E.

*Origin.* The most probable origin for this shock is near the NE end of Yedo Bay.

— 98 —

1882. Feb. 9.

NEMURO or **44.** 10.3 A.M.

— 99 —

Feb. 10.

NEMURO or **44.** 5.37 P.M.

— 100 —

Feb. 11.

**40.** 11.55 P.M.

— 101 —

Feb. 12.

**1.** 5.0 A.M. feeble.

— 102 (Map 66) —

Feb. 12.

TOKIO. *Yamato Yashiki.* 2.49.0 P. M.

Direction NNW 10'. Duration 53<sup>s</sup>.

**7.** 3.18 P. M., feeble, NW.

— 103 —

Feb. 13.

NEMURO or **44.** 0.14 A.M.

— 104 —

Feb. 13.

**2.** 2.55 P. M., feeble, duration 3<sup>s</sup>.

— 105 —

Feb. 14.

**8.** 7.30 A.M.

— 106 —

Feb. 14.

**40.** 11.15 and 11.20 A.M.

— 107 —

1882. Feb. 14.

2. 10.36 P.M. duration 16<sup>s</sup>.

— 108 —

Feb. 15.

2. 4.31.0 A.M. feeble.

— 109 —

2. 5.8.0 A. M. duration 3<sup>s</sup>.

— 110 —

2. 10.3.0 P. M. duration 4<sup>s</sup>.

— 111 —

Feb. 16.

NEMURO or 44. 5.0.0 A. M.

— 112 —

Feb. 16.

CHIBA. 6.59.21 A.M. severe but short.

— 113 (Maps 57 and 91) —

Feb. 16.

TOKIO. *Yamato Yashiki*. About 8.0.0 A.M.

2. 7.2 and 7.50 A. M. First shock lasted 31<sup>sec</sup> and the second 1 minute.—3. 7.0 and 7.52 A. M.—17. 8.30 A. M. S, short.—18. 8.0 A. M. feeble.—21. 8.50 A. M.

CHIBA 7.52.7 A. M. slight, duration 2<sup>s</sup>.

Probably two shocks (see maps 57 and 91)

— 114 (Map 92) —

Feb. 16. 5.33.13 P.M.

TOKIO. *Yama Guchi*. Time 5.32.16. The only record obtained was from a pendulum seismograph. This was approximately N and S. amplitude .2<sup>m</sup>. The shock seems to have been felt very differently in different parts of Tokio.

*Yamato Yashiki*. Time 5.33.13 P. M. Direction ENE 1° Duration 45<sup>s</sup>.

*Yokohama*. Time 5.31.54.

*Chiba*, Time 5.33.48 P. M. This was the most severe of a series of shocks. The series was as follows.

1882. Feb. 16. 6.59.21 A. M. severe, lasted 3<sup>s</sup>  
 7.52.7 A. M. slight „ 2<sup>s</sup> (see 113)  
 5.33.48 P. M. very severe  
 11.51.45 or 11.31.45 P.M. lasted 20<sup>s</sup> (see 115)  
 Feb. 17. 5.57.43 or 5.37.43 P.M. (see 116)  
 9.30.46 P. M. very slight „ 4<sup>s</sup>  
 18 5.49.53 rather severe „ 2<sup>s</sup> (see 120)

A pendulum seismometer indicated a motion N 35 E, amplitude .7<sup>mm</sup> (Fig. 29)

The shock was also felt at:—

**2.** 5.30 P. M. duration 1<sup>m</sup>—**3.** 5.35 P.M. strong—**4.** 5.20 P. M. feeble—**8.** 5.40 P. M.—**20.** 5.33 P. M. feeble.

*Origin.* The best data for the determination of the origin are the time observations at Tokio and Yokohama, the direction observation at Chiba, and the area over which the shock was felt. These data may be taken in conjunction with the area over which previous and succeeding disturbances were felt.

The conclusion is that the origin lay 5 or 10 miles to the eastward of Yokohama or Kanagawa.

*Velocity.* The velocity with which the shock travelled from the Yokohama homoseist on to Yokohama appears to have been about 2800 feet per second.

— 115.(Map 83) —

Feb. 16.

**CHIBA.** 11.51.45 or 11.31.45 P. M. Duration 20<sup>s</sup>. A pendulum seismograph (Fig. 30) indicated motion N 35 E with an amplitude of .9<sup>mm</sup>.

The shock was also felt at:—

**2.** 11.0 P. M. duration 5<sup>s</sup>—**3.** 11.58 P. M.

— 116 (Map 85) —

Feb. 17.

**CHIBA** 5.57.43 or 5.34.43 P. M.?

The shock was also felt at:—

**2.** 3.36 and 5.10 A. M. duration each 4<sup>s</sup>—**3.** 4.30 A. M.

— 117 (Map 29) —

1882. Feb. 17.

**26.** 3.15 P. M. feeble—**27.** 3.20 P. M. feeble, NE—**29.** 3.9 P.M. feeble, N—**30.** 4.0 P. M. feeble, NNW.

— 118 —

Feb. 17.

CHIBA. 9.30.46 P. M. very slight. Duration about 4 sec.

— 119 (Map 83) —

Feb. 18.

**2.** 3.0 P. M. duration 5'.—**3.** 3.35 P. M.

— 120 (Map 87) —

Feb. 18.

CHIBA 5.49.53 P. M. Rather severe. Duration about 2<sup>sec</sup>.

A pendulum seismograph (Fig. 31) indicated a motion N 40 E with an amplitude of 1<sup>mm</sup>. The origin of this shock is probably the same as numbers 114 and 115.

YOKOHAMA 5.50.18 P. M. slight. This shock was also felt in Tokio, and at:—

**1.** 6.0 P. M. feeble—**2.** 6.5 P. M. duration 1<sup>m</sup>.5'.—**3.** 6.10 P. M.—**4.** 5.40 P. M. feeble—**5.** 5.30 P. M. feeble.

— 121 (Map 91) —

Feb. 18.

TOKIO 11.54.0? P. M. Directions ENE 20', NNE 10'. Duration 1<sup>m</sup>. 3'.

**2.** 11.20 P. M. duration 40'.—**3.** 8.54 and 11.0 P. M. The last shock rather strong.

— 122 (Map 86) —

Feb. 19.

**2.** 1.0 A. M. and 4.20 A. M. First shock duration 20'. and the last 50'.—**3.** 2.30 3.55 and 4.30 A. M.—**4.** 1.30 A. M.

feeble—**5.** 1.45 and 4.30 A. M. both  
feeble—**21.** 1.15 A. M.

— 123 —

1882. Feb. 19.

**2.** 7.5 A. M. duration 10<sup>1</sup>.

— 124 —

Feb. 19.

**2.** 3.40 P. M. duration 5<sup>1</sup>.

— 125 —

Feb. 20.

YOKOHAMA 5.54.54 A. M. very slight,

— 126 —

Feb. 20.

NEMURO or **44.** 5.10 P. M.

— 127 —

Feb. 22.

TOKIO. *Yama Guchi.* 5.42.24 A. M.

— 128 —

Feb. 22.

TOKIO. *Yama Guchi.* 4.8.41 P. M.

— 129 (Map 88) —

Feb. 22.

TOKIO. *Yamaguchi.* 6.54.0 P. M. A  
pendulum seismograph gave a small  
diagram.

CHIBA. A pendulum seismograph in-  
dicated 1<sup>mm</sup>. of motion ENE.

YOKOHAMA. A pendulum seismograph  
indicated 2.5<sup>mm</sup> of motion EW.

Other places at which the disturbance was felt were:—

**2.** 6.30 P. M. feeble, duration 1<sup>m</sup>.3<sup>s</sup>—**4.** 6.50 P. M. feeble.

— 130 —

Feb. 26.

**41.** 9.9.4 P. M. very slight (?)



— 131 —

1882. Feb. 27.

**22.** 3.30 A. M. pretty strong, W.

— 132 —

Feb. 27.

**34.** 11.5 A. M. S.—**44.** 11.5 A. M.

— 133 —

Feb. 27.

NEMURO or **44.** 8.35 P. M.

— 134 (Map 121) —

March 1st 1.49.40 A. M.

TOKIO. *Yama Guchi*. Time 1.49.2 A. M. A bracket seismograph (Fig. 32) on a revolving plate indicated an East and West motion lasting about 20 sec. The period was .25 sec. The North and South motion was similar to the East and West only slighter.

*Yamato Yashiki*. 1.49.40 A. M. Direction ENE 1°, NN W, 19'. Duration 11 sec.

YOKOHAMA. From a bracket machine (Fig. 33) recording on a revolving plate it is seen that the motion is chiefly N 10 W and S 10 E. Its duration was about 30<sup>sec</sup>. Maximum amplitude .2<sup>mm</sup>. The period was .25 sec.

A bracket machine on a straight plate (Fig. 34) indicated a motion extending over about 40 seconds. At the commencement the N 15 W component is the larger, but at the 4th 6th and 12th second of the disturbance the N 75 E component is the larger. The chief direction of motion appears to have been about NW. SE. The period at the commencement of the disturbance was .28 sec, but this increased towards the end to nearly 1 sec.

A pendulum on a moving plate (Fig. 35) gave an irregular diagram, only part of which is reproduced. A lengthening in period may be observed about the 17, 18 and 19th second, as in the preceeding diagram.

As timed by Mr. Talbot 1.48.55. Duration about 20 sec. From the above it appears that the shock was felt in Yokohama about 7 sec. *before* being felt in Tokio.

**YAMAGATA.** At 2.9.0 A. M. a rather severe shock lasting about 12 seconds was felt. The direction was about East and West.

The shock was also felt at,

**2.** 1.10 A. M. feeble, duration 6".—**4.** 1.50 A. M. feeble  
**6.** 1.0 A. M.—**7.** 2.0 A. M. feeble, SW—**9.** 2.59 A. M.—**10.**  
2.40 A. M. feeble—**14.** 1.0 A. M.—**15.** 1.40 A. M. feeble—**20.**  
1.50 A. M. feeble—**21.** 1.50—**34.** 2.15 A. M., E.—**36.** 0.10  
A. M.

— 135 (Map 50) —

1882. March 1st 3.28.10 A. M.

**TOKIO.** *Yama Guchi.* At 3.28.2 A. M. A distinct movement being felt for 83 seconds.

Of a series of columns marked 1 to 8, (number eight being the largest) number 1 fell N 40° E, number 3 and 5 fell N 85 E. Two small inverted cones fell about N 40 E.

A pendulum seismograph (Fig. 36) commenced with movements of about .7<sup>mm</sup> approximately E and W. These were followed by two strong lurches E 20 S of about 3.5<sup>mm</sup>. The next movement which was still stronger was SE. It threw the recording pointers off the smoked plate. A second similar seismograph (Fig. 37) shewed motion in all directions but the largest motions of about 7<sup>mm</sup> had a decided direction of E 23 S.

A double bracket instrument shewed motion in the same direction. A bracket seismograph on a revolving plate (Fig. 38) gave a diagram extending over 55<sup>sec</sup>. The portion of this diagram reproduced in Fig. 38 extends from the 10th to the 20th second of the disturbance. The N S component was altogether small. The E and W component was small for the first 10 seconds. About the 13th second after the commencement there was a strong lurch to the SSE. There was a similar lurch at the 18th second. At the commencement of the disturbance the period was .16 sec. but at the end 2.8 sec.

This disturbance was a typical earthquake, commencing with tremors and a shock, and ending with irregular vibrations. These latter died out with a very slow period.

*Dai Gaku.* Prof. Ewing's seismograph indicated that the motion extended over a period of about 3 minutes. It commenced as short waves with a period of .17<sup>s</sup>. The greatest displacement which is E and W is about 5<sup>mm</sup>. The greatest back and forth motion occupied .8<sup>s</sup>. As the disturbance died out the period increased. The North and South component was not recorded. The East and West motion gave a maximum velocity of 19.6<sup>mm</sup> per sec. and a maximum acceleration of 154<sup>mm</sup> per sec. or  $\frac{1}{64}$  of *g*.

*Yamato Yashiki.* At 3.28.10 A. M. Duration 32<sup>s</sup>. Direction ENE 6°4', NNW 2°, NNE 1°10'.

YOKOHAMA. By Mr. Talbot at 3.29.05. As noted by Mr. Favre Brandt by the stoppage of a clock, at 3.30.22.

A pendulum seismograph indicated a NW motion but as the pointers were thrown off the plate a complete diagram was not obtained. A good diagram was however obtained from the friction pointer of the pendulum, indicating a principal motion to the WNW, (see Fig. 39).

A similar seismograph in another part of Yokokama also showed a principal WNW motion.

A bracket seismograph on a revolving plate (Fig. 40) registered the motion as two components, one being N 10 W and the other N 80 E. The duration of the motion was nearly 3 minutes. Up to the 90th second both components of the disturbance are shown, but from the 91st to the 153rd second only the N 10 W motion is given. The N 10 W commenced with a series of minute waves with a period of .25 sec. lasting 18 seconds. At the 18th second an extremely irregular motion set in consisting of shocks or jolts with intervening small waves. Large jolts may be observed at the seconds, indicated by the following numbers,—24, 30, 33, 36, 40, 46, 49, 56, 64, 70, 73, 75. Other violent movements are to be seen on the diagram, but they are not so pronounced. The movement at the 49th second is the largest of the series. Its direction is towards the north. The time taken to make this movement which has an amplitude of 2.5<sup>mm</sup> was about  $\frac{1}{3}$  second. If the motion is simple harmonic the maximum velocity is 11.78<sup>mm</sup> and the maximum acceleration

56<sup>mm</sup> per sec., per sec. A curious point worthy of attention is that whenever the ground has moved suddenly towards the north there has been an equally sudden return, whilst when the ground has moved towards the south, before swinging back towards its normal position, there has been a pause, as is indicated by the flat tops to some of the waves. In some instances as in the N 10 W motion at the 64th second, this pause exceeded a second in its duration.

The period of the small waves which are interposed between and superimposed on the large waves, is about .4 seconds. At the end of the disturbance we find waves having a period of at least 2 seconds, that is to say eight times slower than they were at the commencement.

*Chiba.* A pendulum seismograph (Fig. 41) gave a clear diagram indicating N and S motion.

The shock was observed at 3.28.55 A. M. lasting 32 seconds.

From the above it would appear that the shock was first felt in Tokio, 53 seconds later at Chiba, and 10 seconds still later at Yokohama. At 3.33.0 A. M. a second shock was felt in Tokio, perhaps indicating that the origin was near this place.

The disturbance was also felt at the following places.—

**1.** 3.30 A. M. pretty strong—**2.** 3.40 A. M. strong, duration 2<sup>m</sup>.12<sup>s</sup>—**4.** 3.25 A. M. feeble—**5.** 3.28 A. M. strong—**6.** 3.25 A. M.—**7.** 3.20 A. M. strong, SE.—**8.** 4.0 A. M.—**9.** 3.40 A.M.—**10.** 3.0 A.M. pretty strong.—**13.** 3.25 A.M. pretty strong—**14.** 3.25 A.M.—**15.** 2.30 A.M.—**17.** 3.0 A. M. long.—**20.** 3.30 A. M. feeble.—**21.** 3.25 A. M.—**25.** 3.0 A. M. pretty strong. SW. duration 3<sup>m</sup>.—**26.** 3.50 A. M. pretty strong, long.—**27.** 3.30 A. M. pretty strong, NE.—**29.** 4.0 A.M. strong. W.—**30.** 3.30 A. M. W.—**32.** 3.40 A. M. strong and long.—**39.** 3.5 A. M. moderate.

—— 136 (Map 75). ——

1882. March 1st.

**4.** 8.25 A. M. feeble.—**8.** 8.0 and 8.10 A. M.—**9.** 8.10 A. M.—**10.** 9.0 A. M. feeble.

— 137 (Map 33) —

1882. March 1. TOKIO 2.7.0 P. M.

**4.** 2.10. and 3.25 P. M. The last shock pretty strong.—**8.** 1.40. P. M.—**26.** 2.0 P. M. very feeble—**29.** 1.0 P. M. feeble. W.

— 138 —

March 1.

**10.** 6.0 P. M. feeble.

— 139 (Map 26) —

March 1.

**26.** 8.10 P. M. very feeble—**29.** 9.0 P. M. feeble W.

— 140 (Map 118) —

March 1.

**10.** 10.0 P. M. feeble—**25.** 11.0 P. M. very feeble.

— 141 —

March 2.

**29.** 1.30 A. M. feeble. W.

— 142 (Map 24) —

March 2.

**5.** 6.0 A. M. feeble—**26.** 6.10 A. M. very feeble.

— 143 (Map 28) —

March 2.

**26.** 8.15 P. M. feeble.—**27.** 9.20 P. M. feeble, NW.—**29.** 9.0 P. M. feeble. S.—**32.** 9.13 P. M. feeble.

— 144 (Map. 15) —

March 3.

**29.** 7.0 A. M.? feeble. W.—**34.** 7.10 P. M.? SE.

— 145 —

March 3.

NEMURO or **44.** 10.30 A. M.

— 146 —

1882. March 4.

**10.** 10.0 P. M. feeble.

— 147 —

March 6.

**1.** 7.30 A. M. feeble.

— 148 —

March 6.

**31.** 4.2 P. M. feeble. NE.

— 149 —

March 7.

NEMURO or **44.** 0.54 P. M.

— 150 (Map 42) —

March 7th 11.5.56

TOKIO. *Yama Guchi.* At 11.4.40 or  
11.4.45 P. M.

A pendulum seismograph (Fig. 42) showed a motion in all azimuths the maximum amplitude being .5<sup>mm</sup>. One principal vibration is in a direction E 20 S.

In the record given by a bracket seismograph (Fig. 43) the motion extended over 40 seconds. The E and W motion which is the most prominent commenced first. The N and S motion is not noticeable until the 10th second. The period is .22 sec.

*Yamoto Yashiki.* At 11.5.56 P. M. Direction NNW 1°.50', ENE 1°.30', NNE 50', ESE 10', Duration 40<sup>s</sup>.

YOKOHAMA. Mr. Talbot did not feel this shock. A pendulum seismograph (Fig. 44) showed a decided motion of 1.2<sup>mm</sup> N 23 E.

CHIBA. A pendulum seismograph (Fig. 45) showed a decided motion of .8<sup>mm</sup> N 72 E.

YAMAGATA. The shock lasted 5 or 6 sec. and appeared to be N and S.

KAMAISHI. Many shocks between the 1st and 13th of March.

This earthquake was also felt at,—

**1.** 11.15 P. M. feeble.—**4.** 11.3 P. M. feeble—**7.** 11.0 P. M. feeble, S.—**8.** 11.20 P. M. feeble—**9.** 11.50 P. M.—**10.** 11.5 P. M. strong.—**13.** 10.55 P. M. pretty strong.—**21.** 11.20 P. M.—**22.** 11.30 P. M. duration 7<sup>m</sup>. N.—**26.** 11.0 P. M. feeble—**27.** 11.0 P. M. feeble E—**29.** 10.30 P. M. feeble.

— 151 —

1882. March 8.

**6.** 1.0 A. M., very strong.

— 152 (Map 108) —

March 8.

**21.** 2.25 A. M.—**22.** 2.15 A. M. duration 2<sup>m</sup>.

— 153 (Map 116) —

March 8.

**25.** 10.45 A. M. feeble E.—**26.** 11.0 A. M. very feeble.

— 154 (Map. 3) —

March 8th 4.15.7 P. M.

**TOKIO.** *Yama Guchi.* At 4.15.3 P. M.

A bracket seismograph (Fig. 46) indicated a motion extending over 47 sec. The greatest motion was about .1<sup>mm</sup> the period being .33 sec. The first few seconds the motion which was principally E W was so slight that it was barely visible.

A pendulum seismograph (Fig. 47) showed motion in all azimuths. Two of the principal motions have directions N 27 E and N 60 E. Fig. 48 shows two of the curious curves traced out by the pointers of the seismograph which are clearly visible on the original smoked glass plate.

A pendulum seismograph on a moving plate gave the diagram shown in Fig. 49. The diagram shown at the 31st second was traced when the motion of the plate had ceased. The period appears to have been about .5 sec.

*Yamato Yashiki* 4.15.07 P. M. Direction ENE 1°.20', NNW, 50'. NNE 5'. Duration 1<sup>m</sup>.20<sup>s</sup>.

**YOKOHAMA.** At 4.18.30 or by stopping of a clock at 4.18.18 P. M.

A bracket seismograph on a revolving plate (Fig. 50) gave a diagram during a period of 2½ minutes. Only the 1st sixteen seconds of this is reproduced. The disturbance commenced with a series of small waves with a period of .16 sec. At the 9th second the period became .25 sec., whilst at the end of the disturbance it was still slower. The maximum amplitude does not appear to have exceeded 1<sup>mm</sup>.

**CHIBA.** A pendulum seismograph (Fig. 51) indicated a motion of 1<sup>mm</sup>, N 30 E.

**KAMAISHI.** At 4.15.0 P. M. The disturbance lasted about 15 sec. It was strong enough to cause a forge roll weighing 50 cwts to move back and forth on the ground.

**HAKODATE** or **41.** At 4.17.29 P. M. The shock lasted 4<sup>m</sup>. 33<sup>sec</sup>. The direction by the swing of a lamp was ENE to WSW. The lamp which was suspended by a chain 4 feet long after being once stopped got up a swing of 1 ft. 11 in. On the high ground the shock was not so severe. At the Observatory the time recorded was 4.12.14.

**SAPORO** or **42.** At 4.20.0 P. M. A slight East and West undulation.

This earthquake was also observed at,—

**1.** 4.5 P. M. pretty strong—**4.** 4.18 P. M. feeble—**6.** 4.30 P. M. strong—**7.** 4.45 P. M. feeble NW.—**8.** 4.40 P. M.—**20.** 4.16 and 4.18 P. M. both feeble.—**25.** 3.50 P. M. pretty strong—**26.** 4.20 P. M. pretty strong, long—**27.** 4.5 P. M. feeble SE.—**32.** 4.25 and 4.27 P. M. strong.—**33.** 3.45 P. M. pretty strong.—**34.** 4.15 P. M. S.—**35.** 4.0 P. M.—**36.** 3.45 P. M.—**40.** 4.30 P. M.—**41.** 4.16.10 P. M. and 4.19.29; the first shock, duration 45<sup>s</sup>, sharp.—**42.** 4.13.32 duration 50<sup>s</sup>, gentle. E. W.—**44.** 4.40 P. M.

— 155 (Map 4) —

1882. March 8. 11.54.50. P. M.

**TOKIO.** *Yamato Yashiki.* At 11.54.50 and again at 11.56.48. P. M. Direction of first shock, ENE 30', NNE 20' Duration 38<sup>s</sup>. The duration of the second shock 22<sup>s</sup>.

**YOKOHAMA.** A pendulum seismograph showed .8<sup>mm</sup> of motion N and S. (Fig. 52.)



**HAKODATE** or **41**. At 11.43.0 lasting 15 sec. and again at 11.45.38 lasting 8 sec. The shocks were sharp. At the observatory the shock was timed at 11.40.34. P. M.

**SAPORO** or **42**. At 11.42.0 P. M. two strong shocks lasting 40 sec.

This earthquake was also felt at,—

**8**. 11.30 P. M.—**9**. 11.20 P. M.—**10**. 9.5 P. M. feeble.—**32**. 11.54 and 11.56 P. M. pretty strong.—**33**. 11.40 feeble.—**34**. 11.20 P. M. SE.—**36**. 12.0 and 12.10, feeble.—**40**. 11.45 P. M.—**39**. 11.42. P. M. duration 40°. NNE. moderate.

— 156 —

1882. March 9.

**NEMURO** or **44**. 8.12.0 A. M.

— 157 —

March 9.

**34**. 3.6 P. M. S.

— 158 —

March 9.

**17**. 4.45 P. M. pretty strong.

— 159 —

March 9.

**1**. 8.20 P. M. feeble.

— 160 (Map 14) —

March 9.

**32**. 9.30 P. M. feeble.—**34**. 9.15 SE.—

**35**. 10.0 P. M.—**36**. 9.45 P. M. pretty

strong.—**39**. 9.57.30 P. M. duration

10°. moderate.

— 161 (Map 123) —

March 9.

**10**. 11.35 P. M. pretty strong.—**19**. 11.35

P. M. pretty strong, duration 1<sup>m</sup>.—**25**.

12.45 feeble W.—**33**. 11.20 and 11.40

P. M. feeble.

— 162 —

March 10.

**2**. 6.40 A. M. feeble.

— 163 —

1882. March 10.

NEMURO or **44.** 7.30 A. M.

— 164 —

March 10.

**30.** 4.2 P. M. feeble.

— 165 (Map 122) —

March 10.

**10.** 10.40 P. M. pretty strong.—**19.** 10.40

P. M. pretty strong, duration 1<sup>m</sup>.—**25.**

9.0 P. M. very feeble—**34.** 9.20 P. M. E.

— 166 (Map 49) —

March 11th 8.0.0 P. M.

TOKIO. *Yama Guchi.* By watch at 7.51.7 P. M. From automatic record of clock 7.51.22 P. M. The shock was violent and lamps and pendulums swung through considerable arcs.

A series of columns standing on a stone pedestal fell in various directions. The dimensions of these columns have already been given. The directions in which they fell were as follows.

No.	Cylinders	No.	Truncated cones
1.	N 45 E of Iron	8.	N 96 E of Iron
2.	N 120 E „ „	1.	N 27 E of wood
3.	N 5 E „ „	2.	N 58 E „ „
4.	N 45 E „ „	3.	N 130 E „ „
5.	N 80 E „ „	4.	North „ „
6.	Not set „ „	5.	N 90 E „ „
7.	N 149 E „ „		

Number 4 fell on number 5, whilst number 3 fell on the top of 4 and 5.

From the indiscriminate manner in which the columns fell it is evident that for this particular earthquake their records were of no value.

*Yama Guchi.* Two pendulum seismographs (Fig. 53 and 54) each indicated motion about E 40 S.

From Fig. 53, the earth must have commenced with a series of tremors after which there was a sudden movement of about  $3^{\text{mm}}$  towards the NW which was followed by a movement of nearly  $7^{\text{mm}}$  towards the SE. The succeeding movement to the NW threw the pointer of its plate.

A pendulum seismograph on a moving plate (Fig. 55) shews that the earthquake commenced as tremors, followed by 4 heavy lurches the directions and amplitudes of which were as follows.

N 20 W	amplitude	$3^{\text{mm}}$ .
S 20 E	„	$6^{\text{mm}}$ .
N 20 W	„	$8^{\text{mm}}$ .
S 23 W	„	$6^{\text{mm}}$ .

These movements together with those which follow constitute a series of spirals, wriggles and irregular movements which can only be judged of by reference to the diagram which extends over a period of 17 seconds.

A double bracket seismograph (Fig 56) gave a diagram as irregular as that shewn in Fig 51. Points of resemblance are marked A B C D &c. in each of these two diagrams.

The NE SW loop shown at the 2nd second in each of these diagrams is remarkable. The multiplication in Fig. 52 is less than in Fig. 51. It may also be observed that the double bracket instrument was supported on a tall post the flexibility of which has influenced the character of the diagram.

A vertical spring lever seismograph (Fig. 57) indicated that there had been a slight vertical motion with a period of .14 sec. the amplitude not exceeding .1 or  $.2^{\text{mm}}$ .

*Yama Guchi.* A bracket seismograph (Fig. 58) indicated a principal motion E and W or as combined with the N S motion about ESE. The total duration was  $1^{\text{m}}.20^{\text{s}}$ . The motion commenced with small vibrations, with an amplitude of about  $.1^{\text{mm}}$ . Their period was .25 seconds and they continued for 10 seconds. These were followed by four strong lurches the maximum amplitude of which was not more than  $6^{\text{mm}}$ . After this the disturbance died out as a series of irregular waves with a period of about  $1^{\text{s}}$ . On these waves a number of small

waves are superimposed. From the first three vibrations of shock marked a b c d, on the assumption that the motion was simple harmonic, we can make the following calculations. Let A equal half a semi oscillation or amplitude, T the time in seconds to traverse A, V the calculated maximum velocity and  $a$  the maximum acceleration in millimeters.

	A	T	V	$a$
a to b outward motion	1.5 <sup>mm</sup>	.75 <sup>sec</sup>	13 <sup>mm</sup>	56 <sup>mm</sup>
c to d „ „	3.0	1.	18	54
b to c inward „	2.5	.05	50	500

As the time taken to traverse from b to c can only be estimated approximately on the diagram, the values for V and  $a$  dependent on it must not be regarded as accurate.

Calculating ab and cd without any assumption as to the nature of the motion, we get for ab,  $V = 17$  and  $a = 96$  whilst for cd,  $V = 21$  and  $a = 73$ .

This shock was on the verge of being destructive and one or two chimneys were slightly cracked.

*Dai Gaku.* Prof. Ewing's bracket seismograph indicated that the earthquake commenced as a series of gentle oscillations not exceeding 1<sup>mm</sup> in amplitude and lasting 8 sec. After this there was a sudden lurch in a SE direction the amplitude of which was 7<sup>mm</sup>. After this there were other vigorous motions, the maximum amplitude being 8<sup>mm</sup>.

As the largest wave had a period of 0.7 sec the greatest velocity must have been 31<sup>mm</sup> per second and the greatest rate of acceleration 280<sup>mm</sup> per second per second or  $\frac{1}{35}$  the value of gravity. These calculations are based on the assumption that the motion was simple harmonic. As the disturbance died out the period became longer. (see Trans. S. S. Vol. IV. p. 74).

*Yamato Yashiki* about 7.50.54 P. M. Direction ENE 11°.20', NNE 9°.50', NNW 9°, ESE 2°.30'. Duration 3<sup>m</sup>.20'.

*YOKOHAMA.* As observed by Mr. Talbot at 7.51.33. The observation was probably made at the time of the big shock. By the stoppage of a clock Mr. Favre Brandt observed at 7.52.10 P. M. Two bracket seismographs were thrown off the plates on which they wrote their records. The N 75° E

motion was in one case at least  $12^{\text{mm}}$  and in the other at least  $5.5^{\text{mm}}$ . The movements at right angles to this were respectively at least  $13^{\text{mm}}$  and  $7^{\text{mm}}$ . A possible principal direction resulting from these indications would be  $E 15^{\circ} S$ .

A pendulum seismograph (Fig. 59) without multiplication gave a principal direction  $E 5^{\circ} S$  with a maximum amplitude of  $25^{\text{mm}}$ . Part of this motion will however be due to swinging. This diagram shows a curious complication of motions which the earth must have experienced.

CHIBA. A severe shock at 7.45.17 P. M. lasting 108 sec. A pendulum seismograph (Fig. 60) without multiplication indicated two strong movements of  $10^{\text{mm}}$   $N 15 E$  and  $N$ . These with their respective return motions correspond with the 4 lurches observed at other stations.

This earthquake was also felt at the following places:—

**1.** 7.47 P. M. pretty strong.—**2.** 8.5 P. M. pretty strong, duration  $16^{\circ}$ .—**4.** 7.50 P. M. pretty strong.—**5.** 8.20 P. M., feeble.—**6.** 8.0 P. M. strong.—**7.** 8.50 P. M. strong. SE.—**8.** 8.0 P. M.—**9.** 7.50 P. M.—**13.** 7.50 P. M. strong but short—**17.** 8.2 P. M. pretty strong.—**19.** 7.50 P. M. pretty strong.—**20.** 7.50 P. M. pretty strong.—**21.** 8.0 P. M.—**23.** 7.50 P. M. pretty strong. SW.—**24.** 7.50 P. M. duration  $30^{\circ}$ .—**25.** 7.55 P. M. strong.—**26.** 7.0 P. M. very feeble.—**27.** 8.10 P. M. feeble. E.—**29.** 10.0 P. M. feeble N.—**34.** 7.20 P. M.—**38.** 7.47 pretty strong.

— 167 —

March 12.

**29.** 2.30 A. M. feeble, W.

— 168 —

March 12.

**10.** 8.10 P. M. feeble.

— 169 —

March 12.

**19.** 11.20 P. M. feeble.

— 170 —

March 13.

**36.** 5.4 A. M. pretty strong.

— 171 (Map 76) —

1882. March 13. TOKIO 9.20.0 P. M.

**4.** 7.50 P. M. feeble.—**8.** 9.00 P. M.—

**10.** 8.20.

— 172 —

March 13.

**19.** 11.30 feeble.

— 173 —

March 14.

**25.** 2.10 A. M. feeble.

— 174 —

March 14.

**35.** 6.40 A. M.

— 175 (Map 90) —

March 14. 9.48.52 A. M.

TOKIO. *Yama Guchi.* A slight shock at

9.48.57 A. M. *Yamato Yashiki* at

9.48.52.

This earthquake was also felt at :—

**2.** 9.45 A. M. feeble, duration 3".—**4.**

9.45 feeble—**25.** 9.45 A. M.

— 176 (Map 93) —

March 15.

TOKIO 11.57.42 A. M.

**4.** 11.50 A. M feeble. Also at Sapore.

— 177 (Map 63) —

March 15.

**8.** 0.20 P. M.—**10.** 0.28 P. M. feeble.

— 178 —

March 15.

**8.** 9.0 P. M.

— 179 (Map 117) —

March 17.

**2.** 8.20 A. M. feeble, duration 3".—**9.**

8.15 P. M.?

## — 180 (Map 34) —

1882. March 19.

Tokio. *Yama Guchi*. At 9.25.49 A. M.

A pendulum seismograph (Fig. 61) gave a decided motion of 1<sup>mm</sup> S 10 E. One of the special loops clearly visible in the original is shown in Fig. 62.

*Yamato Yashiki*. At 9.25.33 A. M. Directions ENE 2° NNW 1°.10'. NNE 40'. Duration 21 sec.

*Dai Gaku*. Prof. Ewing's seismograph indicated that the disturbance extended over nearly 4<sup>m</sup>, the greatest displacement was about 2<sup>mm</sup> and the mean period less than 1<sup>sec</sup>. The period increased towards the end of the disturbance.

CHIBA. At 9.25.38, there was a slight shock lasting about 50<sup>sec</sup>. A pendulum seismograph indicated a motion of 2<sup>mm</sup>, N 25 E.

This earthquake was also felt at,—

**1.** 8.45 A. M. feeble—**2.** 9.30 A. M. feeble, duration 1<sup>m</sup>.—  
**4.** 9.25 A. M. pretty strong—**8.** 9.00 A. M.—**25.** 9.20 A. M.  
feeble—**26.** 9.00 A. M. very feeble.

## — 181 —

March 19.

**29.** 3.00 P. M. feeble N.

## — 182 —

March 21.

**36.** 6.00 A. M.

## — 183 (Map 120) —

March 24. Tokio. *Yamato Yashiki*. 4.36.21 P. M.

Direction ENE 20', ESE 20', NNE 10',

Duration 35'.

**36.** 4.45 P. M.

## — 184 —

March 26.

SAPORO or **42.** a slight shock at 8.5.0.  
A. M. or P. M.

## — 185 (Map 79) —

March 31.

Tokio. *Yamato Yashiki* 3.19.53 P. M.

NNW 10'. Duration 9'.

YOKOHAMA. A pendulum seismograph indicated motion which was chiefly E and W.

— 186 —

1882. April 1.

**27.** 10.40 P. M. SW.

— 187 (Map 37) —

April 2nd 4.48.51 P. M.

TOKIO. *Yama Guchi*. At 4.48.54 or 4.47.50 P. M. a moderate shock. From the movement of a lamp and the motion of liquids in bottles, the direction was about NE to SW.

There was a slight motion 5 minutes before this.

A pendulum seismograph (Fig. 63) indicated motion in various directions with an amplitude of .5<sup>mm</sup>.

A rolling sphere (Fig. 64.) on the flat ground at Shinbashi indicated a motion E 22 N of nearly 3<sup>mm</sup>.

A bracketseismograph (Fig. 65) gave a diagram extending over 40 sec. The period was .33 sec. The EW motion is the more pronounced?

*Yamato Yashiki* 4.48.51 P. M. ENE, 2°.40', NNE, 2°, NNW, 1°.10' Duration 44<sup>s</sup>.

CHIBA. A slight shock at 4.49.15 P.M. lasting about 20 sec.

A pendulum seismograph indicated 1<sup>mm</sup> of motion ENE or ESE.

KUMAGAI. A severe shock at 4.48.45 lasting about 45 seconds.

This earthquake was also felt at:—

**5.** 4.48 P. M.—**9.** 4.50 P. M.—**12.** 4.45.—**13.** 4.55 P. M. feeble.—**15.** 4.55 P. M. duration 3<sup>s</sup>.—**27.** 4.00.

— 188 —

April 3.

**27.** 7.00 P. M.

— 189 —

April 4.

TOKIO 6.34.47.

A pendulum seismograph indicated motion of .5<sup>mm</sup> E and W.



— 190 —

1882. April 6.

**6.** 7.20 A. M.

— 191 (Map 55) —

April 8.

TOKIO. *Shinbashi*. A rolling sphere seismograph (Fig. 66) gave a decided motion of 1.2<sup>mm</sup>.

TOKIO. *Yama Guchi*. At 5.17.1 A. M. a slight shock. There appears to have been a previous shock at 2.41.33.

*Yamato Yashiki* at 5.12.37 A. M. ESE, 20'.

This earthquake was also felt at:—

**8.** 5.30 A. M.—**17.** 5.0 A. M. feeble, duration 5<sup>s</sup>.—**21.** 5.00 ?

— 192 —

April 8.

TOKIO 3.21.00

— 193 (Map 36) —

April 9. 3.19.27 P. M.

TOKIO. *Yama Guchi*. By watch at 3.19.21.

By clock at 3.19.20. This is a good example of the accuracy which can be obtained by drawing a watch out of the pocket as compared with an automatic record. The disturbance was slight, lasting about 33 sec.

*Yamato Yashiki* at 3.19.27 P. M. ENE, 20', NNW, 20', NNE, 10', ESE, 10', Duration 1<sup>m</sup>.48<sup>s</sup>.

This earthquake was also felt at,—

**6.** 3.00 P. M.—**8.** 3.50 P. M.—**9.** 3.50 P. M.—**10.** 3.00 P. M. feeble.—**13.** 3.23 P. M. feeble, short.—**15.** 3.30 P. M. duration 2<sup>s</sup>.—**18.** 3.50 P. M.—**29.** 2.00 P. M. strong. W.

— 194 —

April 12.

**33.** 6.10 P. M. feeble.

— 195 —

April 12.

**33.** 11.40 P. M. feeble.

— 196 —

April 13.

**19.** 6.30 A. M. two shocks.

1882. April 14. — 197 —  
**21. 7.00 A. M.**
- April 15. — 198 —  
**9. 8.40 P. M.**
- April 18. — 199 —  
**5. 7.30 P. M. feeble.**
- 200 (Map 64) —  
 April 25.8.23.30 P. M.  
 TOKIO. *Yamato Yashiki*. 8.33.30? P. M.  
 NNW, 10'.  
 CHIBA. A slight shock at 8.29.0 lasting  
 5 sec.
- This earthquake was also felt at:—  
**8. 8.50 P. M.—9. 8.40.**
- 201 —  
 April 29.  
**5. 9.05 P. M. rather strong.**
- 202 (Map 68) —  
 April 30. 11.30.0 P. M.  
 CHIBA. At 11.3.43 P. M. lasting 10 sec.  
**8. 11.30 P. M.**
- 203 —  
 May 1.  
**5. 1.58 A. M. very feeble.**
- 204 (Map 96) —  
 May 2.  
 TOKIO 5.21.00 P. M.  
**1. 5.18 P. M. feeble.**
- 205 —  
 May 3.  
 TOKIO 10.58.27
- 206 —  
 May 5.  
**41. 9.17.9 A.M. duration 3<sup>s</sup>. sharp shock.**

1882. May 9. — 207 —  
**9.** 6.40 P. M.  
 May 17. — 208 —  
 TOKIO 6.50.40 P. M.  
 May 22. — 209 —  
**17.** 10.20 A. M. long.  
 — 210 (Map 26) —  
 May 27. **26.** 6.20 A. M. feeble.—**29.** 5.40, feeble.  
 W.  
 — 211 (Map 27) —  
 June 6. **26.** 11.25 A. M. feeble.—**27.** 11.15 NE  
 pretty strong.—**29.** 10.50 very strong.  
 — 212 —  
 June 6. HAKODATE or **41.** A sharp shock at 6.28.  
 50 P. M. (local time) lasting about 50  
 sec. Another observer says it was  
 very slight.  
 — 213 (Map 48) —  
 June 7. TOKIO. *Yama Guchi.* A pendulum seis-  
 mograph showed a motion of .5<sup>mm</sup> N  
 and S.  
*Yamato Yashiki* 2.26.41 P. M. NNW, 40', ENE, 20'. ESE,  
 20'. Duration 19".  
 This earthquake was also felt at :—  
**4.** 2.30 P. M. feeble.—**7.** 2.40 P. M. feeble. W.—**8.** 2.30  
 P. M.—**10.** 2.40 P. M. pretty strong.—**12.** 2.33 P. M. pretty  
 strong.—**14.** 2.16 P. M.  
 — 214 —  
 June 7. TOKIO. *Yama Guchi.* A slight shock  
 at 4.25.40 P. M.

— 215 —

1882. June 9.

**9.** 9.45 P. M.

— 216 (Map 69) —

June 11.

**5.** 8.30 A. M. feeble.—**8.** 9.00 A. M.

— 217 a —

June 11.

**HAKODATE** or **41** At 6.55.0 P. M. (local time) a slight shock.

— 217 b —

June 13.

**HAKODATE** or **41.** 6.26.0 A. M. slight.

— 218 (Map 46) —

June 14.

**TOKIO.** *Yamato Yashiki* 10.05.38 P. M.

NNW, 20', NNE, 10'. Duration 40".

This earthquake was also felt at:—

**2.** 10.25 P. M. feeble, duration 10".—**4.**

10.20 P. M. feeble.—**10.** 10.20 P. M. feeble.—**20.** 10.0 P. M. feeble.

— 219 —

June 15.

**20.** 0.58 A. M. feeble.

— 220 —

June 16.

**41.** 6.24.54. Duration 50". sharp.

— 221 —

June 25. **34.** 1.10 A. M. S.

— 222 —

July 4.

**35.** 12.00 P. M. pretty strong. SW.

— 223 (Map 95) —

July 10.

**TOKIO** 11.24.00 P. M.

**2.** 11.20 P. M. feeble, duration 30".—**12.**

10.20?

1882. July 13. — 224. —  
**34.** 11.45 A. M. NW.  
 July 15. — 225 —  
**27.** 4.01 A. M. S.  
 — 226 (Map 107) —  
 July 16. **7.** 11.30 P.M. feeble SE.—**12.** 10.20 P.M.  
 feeble.  
 — 227 (Map 102) —  
 July 25.  
**TOKIO.** *Yama Guchi.* A bracket seismograph showed an extremely slight E W motion with a period of .2 sec.  
*Yamato Yashiki.* 1.14.00. P. M. NNE, 50'.  
 This earthquake was also felt at:—  
**4.** 1.05 P. M. feeble.—**12.** 1.15 P.M.  
 feeble.  
 — 228 —  
 July 26. **19.** 11.45 P.M. pretty strong.—**34.** 11.35  
 P. M. feeble.  
 — 229 —  
 July 27. **19.** 10.00 P. M. pretty strong.  
 — 230 —  
 July 30. **2.** 11.30 A. M. Duration 10'.  
 — 231 —  
 Aug. 2. **1.** 9.0 A. M. feeble.  
 — 232 —  
 Aug. 9. **21.** 10.25 A. M.  
 — 233 —  
 Aug. 12. **34.** 2.25 A. M.

— 234 —

1882. Aug. 14.

**33.** 9.30 A. M. W.

— 235 (Map 35) —

Aug. 18.

TOKIO 5.34.20 P. M.

*Dai Gaku.* Prof. Ewing recorded the motion as principally E and W. There is considerable variation in the period of the waves. The largest displacement was about 4.25<sup>mm</sup>.

This earthquake was also felt at:—

**1.** 5.30 P. M. feeble.—**2.** 6.00 P. M. feeble, duration 15'.—**4.** 5.23 P. M. pretty strong.—**5.** 5.30 P. M. very strong.—**8.** 5.0 P. M. very strong.—**10.** 5.20 P. M. pretty strong.—**13.** 5.40 P. M. pretty strong.—**20.** 4.35 P. M. feeble.—**26.** 5.30 pretty strong.—**30.** 6.0 feeble, SW.

— 236 —

Aug. 22.

**38.** 9.35 A. M. feeble.

— 237 (Map 9) —

Sept. 5.

**33.** 12. P. M. N.—**35.** 11.20 P. M. feeble.

— 238 (Map 70) —

Sept. 11.

**4.** 4.27 A. M. feeble.—**5.** 4.09 A. M. feeble.—**8.** 5.0 A. M.

— 240 —

Sept. 14.

**10.** 1.30 A. M. feeble.

— 239 —

Sept. 14.

**4.** 0.25 A. M. feeble.

— 241 (Map 106) —

Sept. 18.

**9.** 10.55 A. M.—**10.** 11.00 A. M. feeble.

— 242 —

Sept. 19.

**8.** 2.00 P. M.

— 243 (Map 61) —

1882. Sept. 29.

TOKIO. 5.17.33 A. M. NNW,  $1^{\circ}20'$ . Duration about  $1^m$ .

*Dai Gaku.* Prof. Ewing's seismograph chiefly indicated E and W motion. Short period vibrations preceded the principal movement. The earthquake dies out with waves of a long period.

This shock was very severe at Atami. Grave stones were rotated and projected. There were other shocks at 9 A. M. and 12 o'clock. (For full account see Trans. SS. Vol. V. p. 95.)

This Earthquake was also felt at:—

**1.** 5.40 A. M. rather strong.—**2.** 5.30 A. M. feeble, duration  $40^s$ .—**3.** 5.30 A. M.—**4.** 5.0 A. M. feeble.—**13.** 5.25 A. M. feeble.—**15.** 5.30. NE, duration  $2^s$ .—**16.** 5.0 A. M. duration  $3^s$ , feeble.—**19.** very strong, in morning.—**21.** 5.30 A. M.—**22.** 5.0 A. M. severe, E.—**23.** 5.40 A. M. SW, severe. (Colour on map ought not to extend to **17.** and **38.**)

— 244 —

Oct. 1.

SAPORO or **42.** 7.10 A. M.

— 245 —

Oct. 2. Atami about 2 A. M.

**3.** 1.30 A. M. feeble.

— 246 —

Oct. 4.

**33.** 5.00 A. M. feeble, W.

— 247 (Map 54) —

Oct. 4.

TOKIO. *Yamato Yashiki.* 10.48.00 A. M.  
NNW,  $1^{\circ}30'$ , NNE,  $10'$ , ESE,  $10'$ .  
Duration  $14^s$ .

ATAMI at 10 A. M. on Oct. 5th?

**3.** 10.30 A. M. feeble.—**15.** 11.45 A. M. E. duration  $3^s$ .—**16.** 11.13. N. duration  $3^s$ .—**17.** 11.10, two shocks, severe.

— 248 (Map 30) —

Oct. 6.

**8.** 11.00 P. M.—**9.** 10.30 P. M.

— 249 —

1882. Oct. 7.

**8.** 4.00 A. M.

— 250 —

Oct. 8.

**2.** 10.00 P. M. feeble, duration 20<sup>s</sup>.

— 251 (Map 78) —

Oct. 9.

TOKIO 5.45.43 A. M. NNW, 30'.

**3.** 5.30 A. M.—**4.** 5.35 feeble, and 5.47. A. M.—**5.** 5.25 and 5.50 A. M. feeble.—**8.** 5.30 A. M.

— 252 —

Oct. 11.

**33.** 2.00 A. M. W.

— 253 —

Oct. 14.

**8.** 9.30 P. M.

— 254 (Map 104) —

Oct. 20.

TOKIO. 3.10.37 A. M. NNW, 3°.40'.

**2.** 3.40 A. M. duration 1<sup>m</sup>.—**4.** 3.19 A. M. severe.—**13.** 3.10 A. M. feeble.—**14.** 3.30 A. M.—**15.** 3.30 A. M., E. duration 4<sup>s</sup>.—**16.** 3.30 A. M. duration 10<sup>s</sup>.

— 255 —

Oct. 20.

**8.** 5.0 A. M.

— 256 —

Oct. 20.

**6.** 12 P. M. feeble.

— 257 —

Oct. 25.

TOKIO 6.55.00

— 258 —

Oct. 28.

**6.** 1.00 P. M.



— 259 —

1882. Nov. 5.

**33.** 6.30 A. M.

— 260 (Map 58) —

Nov. 5.

TOKIO 10.45.34 A. M. duration 24<sup>s</sup>.

**13.** 10.57 A. M. feeble and short.—**15.** 10.30 A. M. SE.  
duration 3<sup>s</sup>.—**17.** 11.11 A. M. two shocks very strong, E.

— 261 —

Noy. 5.

**8.** 1.0 P. M.

— 262 —

Nov. 8.

**26.** 11.50 P. M. pretty strong.

— 263 (Map 73) —

Nov. 10.

**8.** 6.15 A. M.—**9.** 7.50 A. M.—**10.**  
6.10 A. M. feeble.

— 264 (Map 11) —

Nov. 11.

**32.** 8.35, feeble, not long.—**33.** 8.30 S.

— 265 —

Nov. 11.

**9.** 9.18 P. M.

— 266 —

Nov. 11.

**36.** 10.5 P. M.

— 267 —

Nov. 16.

**8.** 7.00 P. M.

— 268 —

Nov. 18.

**5.** 8.27 A. M. feeble.

— 268 b —

1882. Nov. 19.

HAKODATE or **41.** 7.15.0 A. M. slight.

— 269 (Map 56) —

Nov. 21.

**17.** 1.28 P. M. two shocks.—**20.** 0.40  
P. M. feeble.—**23.** 2.0 P. M. feeble,  
SW.

— 270 —

Nov. 22.

**32.** 10.44 P. M. feeble.

— 271 —

Nov. 26.

**8.** 8.0 P. M.

— 272 —

Dec. 2.

**33.** 7.0 A. M. W.

— 273 —

Dec. 3.

**31.** 4.40 A. M.

— 274 (Map 22) —

Dec. 6.

**8.** 11.40 A. M. pretty strong.—**26.** 11.45  
A. M. pretty strong.—**32.** 11.19 A. M.  
pretty strong and long.

— 275 (Map 112) —

Dec. 14.

**8.** 8.0 A. M.—**20.** 7.10 A. M. feeble.

— 276 (Map 23) —

Dec. 23.

**9.** 11.45 A. M.—**32.** 11.25 A. M. pretty  
strong and long.

— 276 b —

Dec. 26. HAKODATE or **41.** 11.45 P. M. slight.

1882. Dec. 27. — 277 (Map 21) —  
**9.** 7.0 P. M.—**26.** 6.30 P. M. feeble.—  
**32.** 6.57, feeble, short. **33.** 7.10  
P. M. strong W.
1883. Jan. 1. — 278 —  
**41.** 4.45.0 P. M. (local), duration 25',  
slight.
- Jan. 3. — 279 (Map 114) —  
**4.** 5.10 A. M. pretty strong.—**15.** 5.10  
A. M. duration 3'. E.
- Jan. 3. — 280 —  
SAPORO or **42.** 3.53.30 P. M. (meantime)  
duration 5'.
- Jan. 4. — 281 —  
**9.** 5.23 A. M.
- Jan. 5. — 282 —  
**16.** 10.45 P. M. feeble.
- Jan. 7. — 283 —  
**9.** 10.0 A. M.
- Jan. 7. — 284 —  
**8.** 7.0 P. M.
- Jan. 10. — 285 —  
**26.** 3.0 P. M.
- Jan. 10. — 286 —  
**4.** 6.30 P. M. feeble.
- Jan. 10. — 287 —  
**8.** 8.0 P. M.

1883. Jan. 10.

— 288 —

**26.** 11.30 P. M.

— 289 —

Jan. 11.

**33.** 2.0 A. M. feeble. S. W.

— 290 (Map 81) —

Jan. 11.

**2.** 6.0 A. M. duration 20<sup>s</sup>, feeble.—**5.**

7.2 A. M. feeble.

— 291 —

Jan. 11.

**2.** 12.0 P. M. feeble, duration 25<sup>s</sup>.

— 292 (Map 71) —

Jan. 12.

**4.** 2.0 A. M. feeble.—**9.** 1.4 A. M.

— 293 (Map 47) —

Jan. 12.

Токио. 2.43.53 P. M. duration 20<sup>s</sup>.

**4.** 2.18 P. M. pretty strong.—**8.** 2.0 P. M.—**9.** 2.20 P. M.—**10.** 2.5 P. M. feeble.—**14.** 2.20 P. M.—**16.** 2.30 P. M.—**20.** 2.26 P. M. feeble.

— 284 —

Jan. 12.

**16.** 9.15 P. M.

— 295 —

Jan. 13.

**26.** 12 P. M. feeble.

— 296 (Map. 20) —

Jan. 14.

**9.** 2.8 A. M.—**32.** 2.20 A. M. feeble, long.—**33.** 1.28, strong, N. W.—**35.** 2.20 A. M. strong N. W.

— 297 —

Jan. 14.

Токио. 3.42.50 P. M.

— 298 (Map 44) —

1883. Jan. 14.

**TOKIO.** *Chirikioku.* 4.40.5 A. M. E,  
12°.10', NW, 10°.50', S W, 6.50, N,  
5.30. Duration 40°.

**CHIBA.** 4.37.7 A. M. duration 45°.

**1.** 4.50 A. M. pretty strong.—**2.** 5.30 A. M. feeble,  
duration 57°.—**3.** 4.20 A. M. duration 20°.—**4.** 4.30 A. M.  
strong.—**9.** 5.0 A. M.—**10.** 4.50 A. M. pretty strong.—**13.**  
4.50 A. M. feeble not long.—**14.** 3.30 A. M.—**15.** 4.30 A. M.  
W. duration 5°.—**16.** 4.30 A. M.—**20.** 4.45 A. M. feeble.—  
**21.** 4.30 A. M.—**26.** 3.0 A. M. very feeble.

— 299 —

Jan. 18.

**9.** 7.56 P. M.

— 300 (Map 73) —

Jan. 19.

**8.** 7.0 A. M.—**9.** 8.10 A. M.—**10.** 8.22  
A. M. feeble.

— 301 (Map 41) —

Jan. 22.

**TOKIO.** 0.20.0 A.M. NW, 6°, SW, 5°.10'.  
N, 2°.50', E 10'

**CHIBA.** 12.20.47, duration 20°, rather  
severe.

**1.** 0.15 A. M. feeble, not long.—**2.** 0.20 and 0.30 A. M.  
both feeble, duration of first 18° and of second 1<sup>m</sup>. 9°.—**3.** 12  
P. M.—**4.** 0.25 A. M. strong.—**5.** 0.30 A. M. pretty strong.—  
**8.** 12. P. M.—**9.** 0.20 A. M.—**10.** 11.50 P. M. strong.—**13.**  
0.45 A. M. strong not long.—**14.** 0.30 A. M.—**15.** 0.30 A. M.  
duration 20°. E.—**16.** 11.30 P. M.—**19.** 11.30 P. M.—**20.**  
0.20, feeble.—**21.** 0.25 A. M.—**26.** 0.20 strong.—**31** 0.40  
A. M.—**32.** 0.23, strong, duration 1<sup>m</sup>.—**35.** 0.30. strong N.  
(The map requires colour up to **35.**)

— 302 —

Jan. 22.

**26.** 1.30 A. M. feeble.

— 303 —

1883. Jan. 22.

**26.** 2.50 A. M.

— 304 —

Jan. 22.

**20.** 4.0 A. M.

— 305 —

Jan. 22.

**26.** 9.30 P. M. very feeble.

— 306 (Map 84) —

Jan. 22.

**1.** 11.30 P. M. feeble.—**2.** 11.50 P. M.  
feeble, duration 13<sup>s</sup>—**3.** 11.40 P. M.

— 307 (Map 7) —

Jan. 23.

**41.** 4.41.4 P. M. duration 25<sup>s</sup>, slight.

SAPORO or **42.** 4.34.30 M. P. (mean time), duration 5<sup>s</sup>. Not  
so strong as in Hakodate.

— 308 —

Jan. 24.

**8.** 12.0 P. M.

— 309 (Map 25) —

Jan. 25.

**9.** 5.10 A. M.—**26.** 4.0 A. M. feeble.

— 310 —

Jan. 26.

**9.** 8.25 A. M.

— 311 —

Jan. 27.

**9.** 6.58 P. M.

— 312 (Map 60) —

Jan. 31.

TOKIO. *Kobu dai gakko*. About 12.15 P.M. This was  
a long slow earthquake. A lamp was observed to wobble but

did not swing. This was succeeded at 12.50 by a second similar movement. The 12.15 shock was felt in Tsukiji.

*Chirikioku.* 0.17.0 P.M. NE, 4°, NW, 3°.10, E, 3°. N, 30'.

This earthquake was also felt at :—

**2.** 0.30 P. M. pretty strong, duration 18'.—**4.** 0.20 P. M. strong.—**8.** 0.50 P. M.—**9.** 0.10 and 0.45 P. M.—**10** 0.35 P. M. pretty strong.—**13.** 1.0 P. M. feeble.—**14.** 0.28 P. M.—**17.** 11.20 A. M. feeble.—**20** 0.20 P. M. feeble.

— 313 (Map 51) —

1883. Jan. 31.

**TOKIO.** *Kobu dai gakko.* At 1.10 P. M. my lecture was almost stopped by the rattling of the windows caused by a sharp earthquake. In the next room the movement was equally severe, but in the chemical lecture room which is in a block of buildings at right angles to where I was, the movement was not observed. About 1.30 P. M. there was another slight shock altogether making four shocks in an hour and a half (see 312.) The 1.10 shock was felt in Tsukiji.

*Chirikioku.* 1.9.14 P. M. NW, 4°, N, 2.50, E, 1.40, NE, 30. Duration 13'.

**CHIBA.** 1.8.48 P. M. Duration 20°, slight but long.

*Kumagai.* 1.0.40 P. M. Duration 30°, severe.

This earthquake was also felt at :—

**4.**—1.15 P. M. strong.—**8.** 1.20 and 1.40 P. M.—**9.** 1.15 and 1.45.—**10.** 1.8 and 1.30, the first being feeble and the second strong.—**13.** 1.30 and 11.50 P. M. the first feeble and the second pretty strong.—**14.** 1.5 and 1.24 P. M.—**16.** 1.20 P. M. duration 15'.—**17.** 1.10 P. M. strong, duration 2<sup>m</sup>.—**20.** 1.16 feeble.—**26.** 1.30 P. M. feeble.

— 314 —

Feb. 2.

**41.** 1.54 P. M (local). Duration 1<sup>m</sup>.40'.

A succession of slight shocks.

— 315 —

Feb. 3.

**26.** 3.30 A. M.

1883. Feb. 3.	— 316 — <b>26.</b> 11.50 A. M.
Feb. 3.	— 317 — <b>8.</b> 5.30 P. M.
Feb. 4.	— 318 — <b>9.</b> 3.59 A. M.
Feb. 4.	— 319 — <b>33.</b> 9.0 A. M. feeble.
Feb. 6.	— 320 — <b>35.</b> 4.50 P. M. feeble. N.
Feb. 7.	— 321 — <b>20.</b> 0.45 P. M.
Feb. 9.	— 322 — <b>35.</b> 4.10 A. M. pretty strong and long. <b>36.</b> 4.35 A. M. pretty strong.
Feb. 9.	— 323 — <b>9.</b> 12.0 P. M.
Feb. 14.	— 324 — <b>9.</b> 9.35 P. M.
Feb. 15.	— 325 (Map 8). — <b>32.</b> 10.0 P. M. strong and long.— <b>33.</b> 9.24 P. M. N. W.



— 326 (Map 71) —

1883. Feb. 16.

**4.** 10.45 P. M. feeble.—**9.** 8.30 and 10.0 P. M.

— 327 —

Feb. 21.

**9.** 1.50 A. M.

— 328 —

Feb. 21.

**2.** 3.22 A. M. pretty strong, duration 16<sup>s</sup>.

— 328 b —

Feb. 26. SAKORO or **42.** 11.20 A. M.

— 329 —

Feb. 27.

**20.** 12.0 P. M. feeble.

— 330 —

Feb. 28.

**41.** 1.50.4 P. M. duration 1<sup>m</sup>.40<sup>s</sup>, slight.  
A series of slight shocks. Also at  
Saporo, slight.

— 331 —

March 3 or 5.

**41.** 10.38.29 or 10.42.25 A. M. (local)  
duration 1<sup>m</sup>.30<sup>s</sup> very slight. Two  
shocks.

— 332 —

March 4.

**5.** 2.30 P. M. very feeble.

— 333 (Map 77) —

March 9.

TOKIO. *Chirikioku*. 10.28.0 A. M. E  
1°.10' NW 20'—**20.** 10.25 A.M. feeble.

— 334 —

March 14.

TOKIO. *Chirikioku*. 4.35.38 A. M. NE  
1°.0' N 30', E. 20'. Duration 8<sup>s</sup>.

— 335 (Map 80) —

1883. March 15.

TOKIO. *Chirikioku*. 7.57.02 A.M. NE 50'.

2. 8.0 A. M. pretty strong, duration 53".—4. 8.5 A. M. feeble.—20. 8.0 feeble.

CHIBA 7.55.34 P. M. very slight.

— 336 —

March 29.

8. 6.30 P. M.

— 337 —

April 3.

26. 3.50 A. M.

— 338 —

April 3.

33. 5 A. M. feeble. W.

— 339 —

April 6.

33. 6.4 A. M.

— 340 —

April 7.

41. 1.5 P. M. duration 50", small.

— 341 —

April 18.

YOKOHAMA 8.42.40 A. M., slight.

— 342 —

April 19.

YOKOHAMA 5.10 A. M. slight.

— 343 —

April 20.

HAkodATE. 3 A. M. N. S. strong and again at 4.43 A. M.

SAPORO. strong, also a second shock.

— 344 (Map 103) —

April 20.

TOKIO. *Chirikioku*. 9.57.10. NE 2°, SE 1°.20', N. 30'. Duration 1<sup>m</sup>.

YOKOHAMA. 9.53. P. M. duration 5<sup>s</sup>, NS.  
gentle.

4. 9.55 P. M. feeble.—14. 10.10 P. M.

— 345 (Map 100) —

1883. April 21.

YOKOHAMA. 9.22.20 A. M. duration 1<sup>s</sup>.  
slight. NS.

14. 9.20 A. M.—20. 9.16 A. M. feeble.

— 346 —

April 23.

33. 6 A. M. W.

— 347 (Map 52) —

April 23.

TOKIO. *Kobu dai gakko*. Shock at 10.34.30 P.M. duration 40<sup>s</sup>, but the bubble of a level was seen to move for 30<sup>s</sup> the after motion of the ground had ceased. The movement was 1 to 2<sup>mm</sup> in jerks to the NNW every 2<sup>sec</sup>. There was a second shock at 10.42.10, perceptible by the level 20<sup>s</sup>.

*Dai Gaku*. Prof. Ewing recorded the first of these earthquakes as lasting over 4½<sup>m</sup>. The greatest motion was 5<sup>mm</sup>. The greatest vertical motion less than 1<sup>mm</sup>. The period was about .8 sec. A principal direction of motion was E 30° N.

*Chirikioku*. 10.32.50 P. M. Directions E. 11°.10'. SW. 10°.10'. N 8°.50'. NW 3°.10'. Duration 1<sup>m</sup>.15<sup>s</sup>. A second shock at 10.41.20.

*Chiba*. 10.23.58 P. M. Duration 10<sup>s</sup>. Again at 10.38.13. Duration 45<sup>s</sup>.

*Yokohama*. 10.28.50. Duration 50<sup>s</sup>. Rather severe N.S. Just before the shock, frogs ceased croaking and remained silent for some time afterwards. A second shock at 10.36.50. Duration 25<sup>s</sup>. N & S, mild.

This shock was also felt at,—

1. 10.50 and 11.0 P. M., both feeble.—2. 11.0 and 11.6 P. M. both feeble, durations 1<sup>m</sup>.9<sup>s</sup> and 20<sup>s</sup>.—3. 11.40 P. M. 4. 10.30 and 10.39 P. M. both feeble.—10. 10.10 and 10.40 P. M. first strong and second feeble.—13. 10.55 and 11.0,

P. M. strong.—**14.** 10.50 and 11.0 P. M.—**15.** 11.0 P. M., duration 40<sup>s</sup>, W.—**16.** 10.28 and 10.35 P. M.—**19.** 8.30 P. M. duration 1<sup>m</sup>, strong.—**20.** 10.30 and 10.37, feeble.—**23.** 10.37 and 10.50 feeble, SW.

— 348 —

1883. April 24.

**10.** 5.20 A. M. feeble.

— 349 —

April 25.

TOKIO about 7.15 A. M.?

— 350 —

April 29.

**33.** 12.0 P. M. feeble.

— 351 (Map 94) —

May 2. TOKIO. *Chirikioku*. 5.17.06 P. M. E 3°30', SW 2°, NW 1°50', N. 1°30'. Duration 20<sup>s</sup>.

CHIBA 5.17.13, P. M., duration 17<sup>s</sup>.

**4.** 5.15 P. M. feeble.—**20.** 5.55 P. M. feeble.

— 352 —

May 2.

**33.** 7.0 P. M. feeble SW.

— 353 —

May 6.

TOKIO. *Chirikioku*, about 6 P. M.

— 354 —

May 10.

**38.** 1.14 P. M. feeble.

— 355 —

May 12.

**33.** 5.20 P. M. S. feeble.

— 356 —

May 12.

**8.** 12.0 P. M.

— 357 (Map 62) —

1883. May 13.

TOKIO *Chirikioku*. 1.18.23 A.M. E  $3^{\circ}30'$ ,  
NW  $10'$ , N.  $10'$ . Dogs were heard to  
howl after this shock.

CHIBA. 1.22.0 A. M. duration  $30^{\circ}$ . very  
slight.

4. 1.10 A. M. pretty strong.—20. 1.7 A. M. feeble.—  
22. 1.20 A. M., feeble, SE. duration  $3^m$ .

— 358 —

May 16.

38. 6.43 A. M. feeble.

— 359 (Map 6) —

May 18.

33. 7.50 A. M. feeble, S.—35. 7.55  
A. M. feeble, N.—41. 7.18.37, slight  
and short.

— 360 (Map 98) —

May 23.

TOKIO. *Chirikioku*. 5.58.52. E  $1^{\circ}20'$ ,  
NW  $1^{\circ}10'$ . N  $1^{\circ}$ . SW  $30'$ . Duration  
about  $1^m$ .

I was walking about in the garden at the time and did  
not feel it. An inspection of the map shows that the long axis  
of the area over which this shock was felt, corresponds with  
the principal direction of motion as observed in Tokio.

2. 6.4 P. M. pretty strong, duration  $53^{\circ}$ .—3. 5.55 P. M.  
4. 5.48 P. M. feeble.—8. 6.0 P. M.—13. 6.0 P. M. feeble.

— 361 —

May 24.

41. 3.51.4. Two shocks, the first short,  
the second  $30^{\circ}$ .

— 362 —

May 24.

8. 7.0 P. M.

— 363 (Map 56) —

1883. May 28.

TOKIO. *Chirikioku* 1.15.10.

**15.** 1.20 P. M., duration 10<sup>s</sup>. E.—**17.** 1.20 P. M. two shocks, strong.—**20.** 1 10 P. M. feeble.—**23.** 1.15 P. M. pretty strong, SW.

In *Yokohama* Mr. Talbot in his garden did not feel the motion but distinctly saw a large motion in his house.

— 364 (Map 67)

May 29.

TOKIO. *Chirikioku* 6.07.02 E. 1° 50', NW 1° 50', SW 40', N 10'. Duration 21<sup>s</sup>.

CHIBA. 6.5.14 P. M., duration 45<sup>s</sup>, slight.

**4.** 5.57 P. M. feeble. **8.** 5.0 P. M.

— 365 —

June 9.

**8.** 7.0 A. M.

— 366 —

June 9.

**33.** 6.0 P. M. feeble, SW.

— 367 (Map 43) —

June 10.

TOKIO. *Chirikioku*, 10.15.0 P. M. N 18° 20', NW 14° 10', E 11° 10'. NE 11.°0'.

Duration 1<sup>m</sup> 10<sup>s</sup>

YOKOHAMA. 10.8.20. Duration 1<sup>m</sup> 20<sup>s</sup>.

NS. very severe.

CHIBA. 10.12.53. Duration 2<sup>m</sup> 15<sup>s</sup>.

Severe.

This earthquake was also felt at;—

**1.** 10.30 P. M. pretty strong.—**2.** 10.50 P. M. pretty strong, duration 2<sup>m</sup> 30<sup>s</sup>.—**4.** 10.10 P. M., strong.—**5.** 10.40 P. M., pretty strong.—**8.** 10.0 P. M.—**13.** 10.10 P. M. strong.—**16.** 10.5 P. M.—**20.** 10.10 P. M., feeble.—**21.** 10.0 P. M.—**23.** 10.10 P. M. feeble.

— 367 b —

1883. June 11.

SAPORO or **42.** 5.30 A. M.

— 368 (Map 97) —

June 12.

TOKIO. About 6.13.0 P. M.

**2.** 6.0 P. M., pretty strong, duration 1<sup>m</sup> 50<sup>s</sup>.—**4.** 5.55 P. M. pretty strong.—**5.** 6.25 P. M., feeble.

— 368 b —

June 24.

HAKODATE or **41.** 3.54 P. M.

— 369 —

June

CHIBA. 2.55.2 A. M. duration 3<sup>s</sup>.

— 370 —

June 19.

**4.** 10.10 P. M. feeble.

— 370 b —

June 24.

SAPORO or **42.** 3.53.48 P. M. EW.

— 370 c —

July 4.

HAKODATE or **41.** 3.07 P. M. also at Sapporo.

— 371 (Map 99) —

July 13.

TOKIO. 3.44.00 about.

**8.** 5.0 P. M.—**14.** 4.0 P. M.

The colour on the map does not extend sufficiently far towards the South.

— 372 —

July 13.

**8.** 11.0 P. M.

— 373 —

July 16.

**8.** 7.0 A. M.

— 374 —

1883. July 18.

**33.** 7.0 P. M. W.

— 375 —

July 18.

TOKIO. About 8.50.00 P. M.

— 376 —

July 19.

**33.** 6.0 A. M., feeble, W.

— 377 —

July 27.

**16.** 5.7 P. M.

— 378 (Map 67) —

July 27.

**4.** 7.40 P. M., feeble.—**8.** 7.30 P. M.

— 379 —

July 27.

TOKIO. About 2.25 A. M.

— 380 —

July 29.

**33.** 3.20 and 4.6 P. M. feeble S.

— 381 —

Aug. 2.

**41.** 5.36.4 A. M., sharp.

— 381 b —

Aug. 9.

SAPORO or **42.** 11.07 P. M.

— 382 —

Aug. 6.

**4.** 11.59 P. M., feeble.

— 383 —

Aug. 17.

TOKIO. 2.38.41 P. M. Duration 24<sup>s</sup>.



	— 384 —
1883. Aug. 30.	<b>38.</b> 2.20 P. M., feeble.
	— 385 —
Sept. 13.	<b>38.</b> 0.15 A. M., feeble.
	— 386 —
Sept. 15.	<b>5.</b> 7.30 P. M., feeble.
	— 387 (Map 69) —
Sept. 23.	<b>5.</b> 6.30 A. M.— <b>8.</b> 7.20 A. M.

### III. GENERAL RESULTS.

#### 1. *Distribution in Space.*

The number of shakings which have been felt at different places in north Japan are given in the right hand column of table I. The numbers in the left hand column of this table denote towns at which observations were made. It will be seen that the greatest number of earthquakes were felt at number 8 (Asaw) where 82 distinct shocks were recorded. Other places situated near to number 8, like 9, 10 and 4 (Mito, Shimodate and Sakura) also record a high number of disturbances.

Many shocks have been quite local in their character not having been sensible over an area greater than 50 square miles.

From an inspection of the table II in which these local shocks are indicated, it appears that there have been 198 local shocks on the seaboard and 56 inland, or a total of 254 local shocks out of the 387 which have been recorded. Some of the local shocks observed at places on the coast may have extended over an area greater than 50 square miles.

TABLE I.

Places.	1881			1882												1883									Total.
	October	November	December	January	February	March	April	May	June	July	August	September	October	November	December	January	February	March	April	May	June	July	August	September	
T	1	1	6	5	10	13	6	3	3	2	1	1	4	1	..	6	..	2	4	4	2	2	..	..	77
Y	1	1	5	5	9	8	3	..	2	..	1	1	2	..	..	6	..	1	5	2	1	..	..	..	53
1	..	3	2	2	3	13	..	1	..	..	2	1	..	..	..	3	..	..	1	..	..	..	..	..	32
2	..	4	3	2	17	8	..	..	..	2	..	1	3	..	..	6	..	1	1	1	2	..	..	..	52
3	1	5	2	2	10	7	..	..	..	..	1	1	3	..	..	6	..	1	1	1	2	..	..	..	43
4	1	7	7	6	10	12	2	..	2	1	1	3	3	..	..	9	1	1	2	4	4	1	1	1	79
5	..	1	..	2	2	3	3	1	1	..	1	1	1	1	..	3	..	1	..	2	..	..	2	..	25
6	..	6	5	4	3	6	3	..	1	..	1	1	3	..	..	4	..	..	1	..	2	..	..	..	36
7	1	2	5	5	3	8	2	..	2	3	1	1	2	1	..	5	..	..	1	..	1	1	..	..	43
8	2	3	5	8	6	12	4	..	..	2	1	2	6	5	2	10	2	..	4	2	4	..	1	..	82
9	1	2	5	8	2	12	4	1	1	..	1	1	1	2	3	14	3	..	..	..	1	..	..	..	62
10	1	2	5	8	1	15	2	..	2	..	1	2	..	1	1	6	..	..	2	..	1	..	..	..	50
11	1	1	3	4	..	5	..	..	..	..	..	..	..	..	..	1	..	..	..	1	..	..	..	..	16
12	1	3	6	5	..	4	2	..	1	3	..	..	1	..	..	4	..	..	1	..	1	..	..	..	32
13	1	1	3	1	1	3	1	..	..	..	..	1	1	1	3	5	..	..	1	1	..	..	..	..	24
14	1	1	3	2	1	2	..	..	1	..	..	..	1	..	..	5	..	..	3	..	..	1	..	..	21
15	1	1	2	3	1	4	3	..	..	..	..	..	2	2	..	5	..	..	..	1	1	..	..	..	27
16	1	1	3	2	1	4	3	..	..	..	..	1	2	2	..	7	..	..	2	1	1	1	..	..	32
17	..	..	3	3	1	3	1	1	..	..	..	1	1	2	..	2	..	..	..	1	..	..	..	..	16
18	..	1	2	1	2	4	2	..	..	..	..	1	1	1	..	4	..	..	1	1	1	..	..	..	21
19	..	..	..	..	..	4	1	..	..	2	..	1	1	..	..	1	..	..	1	..	..	..	..	..	10
20	1	2	2	2	3	5	..	..	2	..	1	1	..	1	1	5	2	2	2	3	1	..	..	..	36
21	..	1	1	..	1	5	2	..	..	..	1	1	2	1	..	3	..	..	1	1	1	..	..	..	21
22	..	..	2	..	2	4	..	..	..	..	..	1	..	1	..	..	..	..	1	2	1	..	..	..	15
23	..	..	2	..	1	2	..	..	..	..	..	1	..	1	..	..	..	..	1	1	1	..	..	..	10
24	..	..	1	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	2
25	..	3	2	2	2	13	..	1	..	..	2	1	..	..	..	..	..	..	..	..	..	..	..	..	28
26	1	..	3	10	3	12	1	1	1	..	1	..	..	1	3	12	2	..	1	..	1	..	..	..	53
27	1	..	2	6	3	9	3	..	1	1	1	..	..	..	3	2	..	..	..	..	..	..	..	..	33
28	1	..	..	2	2	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	6
29	1	1	2	9	2	12	1	1	..	..	2	..	..	..	..	1	..	..	..	..	1	..	..	..	32
30	1	..	1	5	1	4	..	..	..	..	2	..	..	..	..	1	..	..	..	1	..	..	..	..	16
31	1	..	1	2	..	2	..	..	..	..	..	..	..	1	1	1	..	..	..	..	..	..	..	..	9
32	1	..	2	4	1	7	..	..	..	..	..	..	..	2	3	2	1	..	..	..	..	..	..	..	23
33	1	..	3	6	1	6	2	..	..	..	1	1	2	2	2	2	2	..	4	1	1	3	..	..	40
34	1	..	6	6	2	8	..	..	1	2	1	..	..	1	2	1	1	..	..	..	..	..	..	..	30
35	1	1	1	4	..	3	..	..	..	1	..	1	..	..	..	1	1	..	..	1	..	..	..	..	17
36	1	..	2	4	..	7	..	..	..	..	..	..	..	1	..	..	1	..	..	1	..	..	..	..	17
37	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
38	..	..	2	1	..	1	..	..	..	..	1	1	..	..	..	..	..	..	2	..	..	1	1	..	10
39	1	1	5	9	1	4	..	..	..	..	..	..	..	..	..	1	..	..	..	1	..	..	..	..	23
40	..	..	1	3	2	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	8
41	4	..	2	..	1	3	..	1	3	..	..	..	..	..	..	2	2	1	1	2	..	1	..	..	22
42	2	..	2	..	..	3	..	..	..	..	..	..	1	..	..	2	..	..	..	..	..	..	..	..	10
43	1	..	1	5	8	4	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	19
44	1	..	1	5	9	4	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	20
45	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	0
46	..	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2
Total.	36	57	122	160	126	272	51	11	24	19	26	29	40	31	22	148	21	10	41	36	36	13	3	5	

Winter Months . . . . .1045  
Summer Months . . . . . 294

TABLE II.

On the coast

Inland

Number of Place	Number of Shocks	Number of Place	Number of Shocks
Tokio	17	22	2
Yokohama	2	16	3
19	5	10	8
25	9	12	4
21	2	7	1
20	3	14	1
2	14	29	5
3	2	40	5
9	13	42	5
8	22	35	4
5	7	34	8
6	6	38	5
4	8	17	2
26	16	31	2
27	3	30	1
32	1	Total.	56
39	3		
36	3	<p>The high number of local shocks recorded for Tokio may be due to their having been many observers and instruments in that city the latter indicating shocks which otherwise would have been passed by unnoticed.</p>	
33	19		
41	15		
44	17		
46	1		
Total.	198		

The majority of the remaining 133 shocks, extended over a land surface the average diameter of which was about 45 miles. Some four or five shocks created a disturbance over the whole of Yezo and the eastern coast of Nippon as far south as Tokio or Fujisan. The *land* area shaken equalled about 44,000 square miles. The total area shaken had probably a radius of at least 150 miles. These latter shocks originated

far out at sea and consequently have not been so alarming in their character as many which originated nearer to or beneath the land.

## 2. *Simultaneous shocks.*

A curious set of disturbances are those which have occurred simultaneously at distant localities whilst intermediate stations have not recorded any disturbances.

Earthquakes number 161 and 165 are examples of these disturbances. Each of these earthquakes was only felt at stations 19, 25, 10 and 34. Both earthquakes occurred on succeeding nights about 11 P. M. That these particular stations which are widely removed from each other should on two succeeding nights have coincided in reporting earthquakes can hardly be regarded as accidental.

A tabular view of these coincidences is as follows.

Number of Earthquake.	Places at which felt.	Number of Map.
161	19, 25, 10, 33.	123
165	19, 25, 10, 33.	122
140	25, 10.	118
153	25, 26.	116
183	Tokio, 36	120
10	Tokio district, 39.	111
97	Tokio district, 26 and 27.	110
83	26, 14.	115
134	Tokio district, 30, 34 and 36.	121
85	Tokio district, 31 and 30.	119
179	2, 9.	117
179	15, 4.	114
87	38, 33 and 34.	113
132	34 and 46.	

From this table it will be seen that it has not been uncommon to have an earthquake at or near Tokio in the south, together with one at some place like 33, 34, 36 or 39 about 200 miles distant up the coast.

It is of course possible that there has not been an exact synchronism in these shocks inasmuch as the exact time at which they occurred is unknown.

### 3. *Origins of Earthquakes.*

By reference to the observations which were made on various earthquakes it will be seen that in many instances materials have been collected which are sufficient for the approximate determination of the origins from which many disturbances have radiated.

For example if an earthquake was only felt at station 12, it is assumed that it must have originated near that station. If however an earthquake was felt at a large number of stations, but at one of them it was very severe or was there followed by a series of small shocks, it is assumed that the origin was probably nearer to the one where then had been the greatest seismic activity. In these determinations, instrumental observations on direction and time have also been of great assistance.

The approximate origins which have in this way been determined are indicated by a series of areas marked alphabetically in map No. 124

The areas from A to H are in the ocean, I to N are either on the sea bord or very near to the sea bord, while the remaining areas are inland.

The earthquakes originating about C are those which have been felt over all Yezo and the eastern side of Nipon as far south as Tokio. Those originating in E have only been felt about 26 and 27. In some instances it has been difficult to determine in which of two contiguous areas the origin of a certain earthquake ought to be located. Thus an earthquake considered to have come from the southern end of area D, may perhaps have originated at the northern end of E. Again with certain earthquakes which shook the mouth of the Tone-gawa it has been a somewhat arbitrary determination to say whether they originated in T, K or F.

As contiguous areas will be taken together when considering the general distribution of seismic activity, irregularities in determination of origin like those just considered, will not influence the general results.

The number of earthquakes originating in the areas which have been indicated, are shown in the following table.

They are also shown on the map.

I		II		III	
Origins beneath the Ocean		Origins on or near the Sea bord		Origins inland	
Area.	No. of Shocks	Area.	No. of Shocks	Area.	No. of Shocks
A	17	T	8	O	1
B	17	J	62	P	7
C	6	K	39	Q	3
D	42	L	6	R	10
E	38	M	18	S	35
F	77	N	4	T	2
G	14	—	—	U	6
H	7	—	—	—	—
Total	218	Total	137	Total	64

The general result is that the greater number of earthquakes felt in north Japan have originated beneath the ocean. If we consider I and II as belonging to the same group then we may say that 355 earthquakes out of 419 or *84 per cent* have originated beneath the ocean or on the sea bord.

The district which is the most shaken is the flat alluvial plain of Musashi following the line of the river Tonegawa. This district may include the areas F, J, K and S, from which area 213 earthquakes out of 419 have originated.

The number 387 has become 419 in this table because an earthquake which was simultaneously felt at two distant stations has been reckoned as belonging to two distinct areas.

This area of greatest seismic activity forms one of the flattest parts of Japan. The large number of earthquakes which have been felt on the low ground and the comparatively small number which have been felt in the mountains is certainly remarkable.

It must also be observed that in the immediate vicinity of active or extremely recent volcanoes the seismic activity has been small. An inspection of the map showing the

general distribution of volcanoes in Japan and the regions of greatest seismic activity indicate that the volcanic and seismic activity are not directly related to each other. If they are connected, we may ask why are earthquakes only frequent on one side of the band of volcanoes which partially surrounds the Musashi plain, whilst amongst the volcanoes and on the opposite side of them from Tokio, earthquakes are comparatively rare? It may also be remarked that the side of Japan on which earthquakes are the most frequent is the side which slopes down steeply beneath an ocean which at 120 miles from the coast has a depth of about 2000 fathoms, whilst on the opposite side of the country at the same distance from the shore the depth is only about 140 fathoms. Another point not to be overlooked is the fact that the district where earthquakes are the most numerous is one where there is abundant evidence of a recent and rapid elevation.

In all these respects the seismic regions of Japan hold a close relationship to similar regions in South America where we have earthquakes originating beneath a deep ocean, at the foot of a steep slope on the upper parts of which there are numerous volcanic vents, whilst on the side of this ridge opposite to the ocean earthquakes are rare. With regard to the Musashi area it may also be remarked that sediments brought down by numerous rivers from the higher parts of the country are accumulating on it at a very rapid rate.

#### 4. *Relation of earthquakes to various Natural Phenomena.*

Almost all seismologists who have compiled lists of earthquakes have by means of tables and curves endeavoured to show the relation between these disturbances and other natural phenomena. Perrey and Mallet amongst other things have shown us that earthquakes are more frequent at the following times.

- 1°. In relation to the moon. Earthquakes are frequent at the syzgies, when the moon is in perigee and when the moon is near her meridian passage.
- 2°. In relation to the sun. Earthquakes are more frequent during the winter months.

These and other laws which have crept into text books of Geology are in the majority of cases founded on extremely slender evidence and we must remember that the exceptions to them are very numerous.

As investigations similar to these have already been made for the earthquakes of Japan, by Messrs Knipping, Naumann and other workers, it is not my intention to repeat them unless they indicate laws more definitely than those which have previously been made.

(a) *Relation of earthquakes to the seasons.*

The number of earthquakes which have been felt in different months and during different seasons is shown in the following table.

	1881	1882	1883	Total	
January	—	40	36	76	} 195
February	—	44	17	61	
March	—	52	6	58	
April	—	17	14	31	} 70
May	—	8	14	32	
June	—	11	6	17	
July	—	9	10	19	} 39
August	—	6	4	10	
September	—	7	3	10	
October	7	15	—	22	} 83
November	16	13	—	29	
December	26	6	—	32	
Winter months.....				278	
Summer months .....				109	
Total .....				387	

From this table it appears that the greater number of earthquakes occurred during the coldest months that is in January, February and March. Or if we take these months in conjunction with October November and December to represent the winter, the remaining months being the summer, the winter earthquakes were to the summer earthquakes as 278 to 109.



These results accord with those previously obtained for the Tokio area alone, by observations lasting over a long period of years. The only value of the table just given is that it shows the winter law, more definitely than it has hitherto been represented.

#### 6. *Relation of Seismic Intensity to the Seasons.*

In the last table only the number of earthquakes which have been felt were considered, and the 278 during these winter months might have been exceedingly small disturbances whilst the 109 in summer might have been severe.

Assuming that the observation stations are evenly distributed over the area in which observations have been made, some approximation to the intensity may be obtained by giving a value to each earthquake corresponding to the number of stations at which it was felt. A result like this is given in Table I, from which it will be seen that 737 records were sent in for January February and March, 199 for April May and June, 95 for July August and September and 308 for October November and December. Summing these up, we obtain the number 1045 to represent the winter intensity, and 294 to represent the summer intensity, *that is to say, the winter intensity is nearly three and a half times as great as the summer intensity.*

#### 7. *Frequency of Earthquakes in all Japan.*

For about half of the empire of Japan, in two years, the first being one in which earthquakes were frequent and the other a year when earthquakes were few, 387 shocks were registered without the aid of instruments. Had instruments been employed,—if we may judge from the Tokio district where there were many instruments,—this number would have been considerably increased. For the whole of Japan we may therefore safely assert, that on the average there is at least one earthquake per day. There may possibly be two or three.

This is an estimate which some Seismologists have

given for the whole world, a deduction based on earthquake calendars published annually in Europe. If the records contained in these calendars are as imperfect for other parts of the world as they are for Japan, we might conclude that in the world generally there are at least 20 earthquakes per day, or perhaps 50.

8. *The occurrence of earthquakes in relation to changes in temperature.*

Hitherto the relation of earthquakes to changes in temperature has only been indicated by means of tables and diagrams showing the relation of earthquakes to the months and seasons.

In the first of the accompanying figures, the dotted line shows the change in the mean monthly temperature at Tokio, whilst the full line indicates the number of earthquakes which have been felt in successive months.

The lowest temperatures it will be observed are from December to March, the highest being in July and August. The greatest number of earthquakes have occurred during the former of these two seasons, but it will be noticed that there is a tendency for this period of maximum seismic energy to continue on into April.

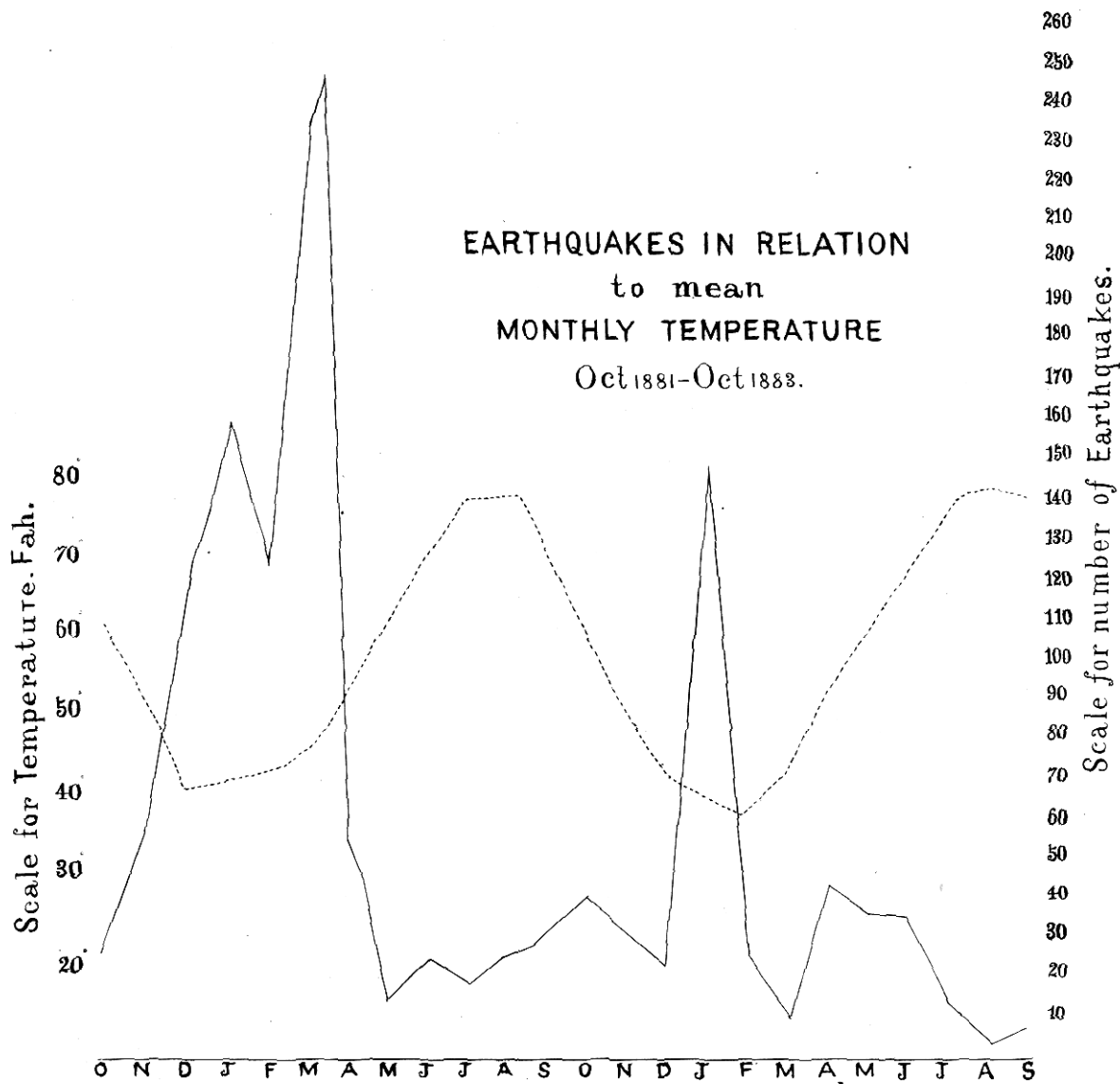
This is more definitely shown in the second figure where the relationship of earthquakes recorded in Tokio to mean monthly temperatures, is given for a period of 6 years.

In this table we see a *general coincidence between the maximum of earthquakes and the minimum of temperatures.*

It must however be noted that the sinuses of the temperatures curves are generally a little in advance of the crests of the earthquake waves.

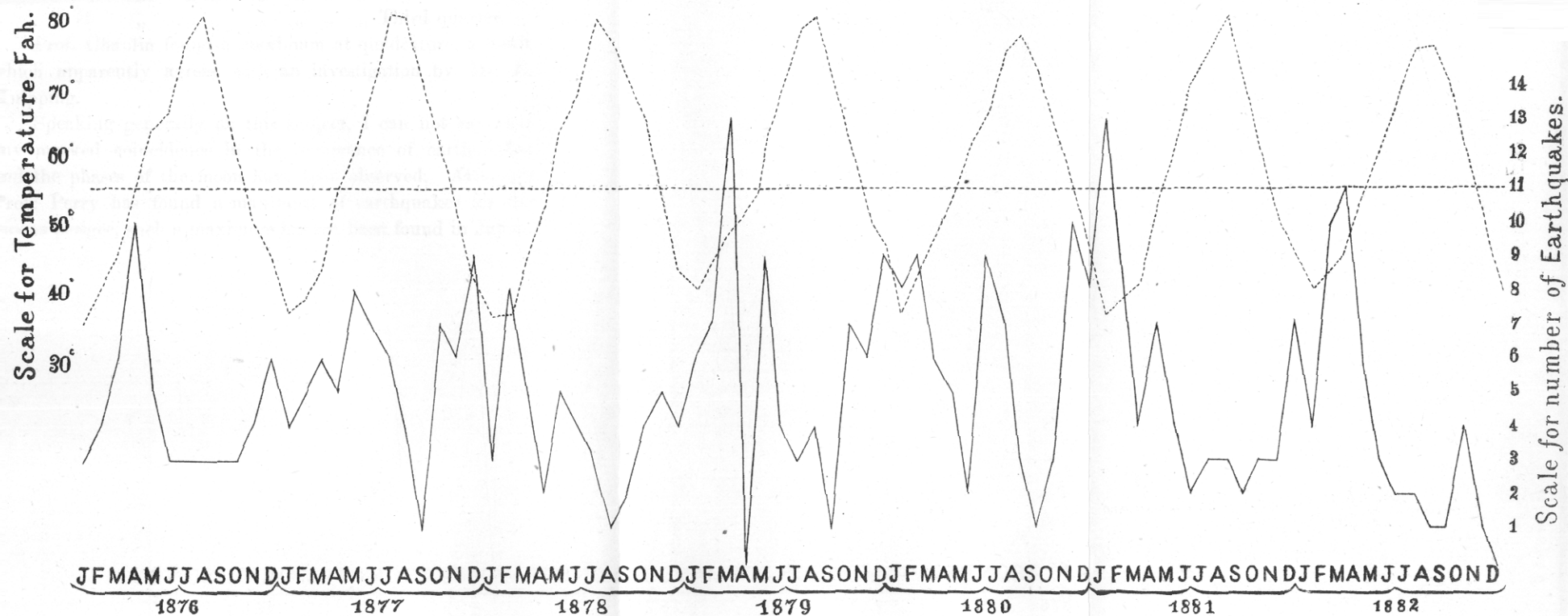
Had the temperature curve been that of the waters surrounding Japan, inasmuch as water increases in temperature slowly and parts with it slowly, the occurrence of earthquakes with the minima temperatures might have been still more marked.

As we have already shown that the majority of the earthquakes felt in Japan originate beneath or near the



*(Temperature shewn by dotted lines.)*

# EARTHQUAKES RECORDED IN TOKIO IN RELATION TO MEAN MONTHLY TEMPERATURE.



(Temperature shewn by dotted lines.)

ocean, this coincidence is significant of a possible connection between the two.

9. *Earthquakes in relation to the relative position of the Moon and Sun :*

The results I obtained show that out of 264 earthquakes,

72 occurred at or within 4 days of New moon

52     "     "     "     "     "     "     First quarter

65     "     "     "     "     "     "     Full moon

75     "     "     "     "     "     "     Third quarter

Prof. Chaplin found a maximum at quadrature, a result which apparently agrees with an investigation by Mr. E. Knipping.

Speaking generally on this subject, I can not say that any marked coincidence in the occurrence of earthquakes and the phases of the moon have been observed. Although Prof: Perry has found a maximum of earthquakes for the moons perigee, such a maximum has not been found in Japan.

Origins.	Hours before high water						High water at Tokio	Hours after High water					
	6	5	4	3	2	1	0	1	2	3	4	5	6
A	2	..	1	..	1	1	2	4	2	1	4	..	..
B	3	1	2	2	1	1	2	2	3	2	1	..	..
C	1	..	1	1	..	..	..	..	..	2	1	1	..
N	1	..	..	..	1	1	..	1	..	..	..	..	..
D	7	7	2	2	5	2	4	2	3	4	3	2	..
M	2	1	3	1	3	1	1	3	2	2	..	..	..
E	3	5	5	5	5	6	3	3	2	4	3	3	..
L	1	1	..	1	1	..	..	1	1	..	1	2	..
F	11	10	4	9	10	4	6	12	10	8	4	10	..
K	5	5	2	2	6	5	2	4	7	2	3	5	..
J	6	10	9	4	5	6	8	10	5	3	8	9	..
S	6	2	1	3	5	2	4	4	4	5	2	5	..
R	..	..	1	1	2	..	..	2	1	..	2	3	..
I	2	2	..	1	..	1	2	1	..	1	1	..	..
H	1	2	..	..	..	1	..	2	..	2	..	..	..
G	2	1	1	2	2	1	1	1	2	3	..	..	..
Q	..	..	2	1	..	..	..	1	1	..	..	..	..
P	3	1	..	..	2	1	..	..	..	..	..	1	..
O	..	..	..	..	..	..	..	..	..	..	..	..	..
T	..	1	1	..	..	..	..	1	1	..	..	..	..
U	..	..	1	2	..	1	..	1	2	..	..	..	..
	56	49	36	37	49	34	37	55	46	39	33	41	..
	146		122		126		118						

### 10. *Earthquakes and the Tides.*

The foregoing table shows the relation between the occurrence of earthquakes and the state of the tides. Inasmuch as there are inaccuracies in the times at which earthquakes have been observed, it has not been considered necessary to carry the comparison with the state of the tide to within fifteen minutes.

In the accompanying table, *O* indicates one hour at the time of high water at Tokio, that is half an hour before high water and half an hour after high water. The numerals to the right and left of *O*, indicate hours before and after high water at Tokio. The letters A B C &c. denote areas from which shocks have originated. The number of shocks which have originated in these various areas at different hours of the tide are given by numerals horizontally following the letter of the station to which they refer.

Adding up these various columns and grouping them in four periods of approximately three hours each, we see that there has been a slight preponderance of earthquakes at the three hours representing low water. An error tending to obscure this general result, is the want of a correction for the state of the tide in the northern areas like A B C &c. where the tide is from 1 to 1½ hours earlier than in the south. Another error is the inclusion in the list of areas like Q T U which are situated far inland and removed from any direct influence of the tide on the coast.

The best result is seen by taking areas where earthquakes have been the most numerous and for which the time of high water is practically the same in all. Such a group of areas is the group F K S T.

This area shows that at low water there were 84 shocks, at half tide rising 60, at full tide 67, and at half tide falling 61. *Comparing together the low water earthquakes with those which occurred at high water we see that the former are about 11.2 per cent more numerous than the latter.*

### 11. *Results relating to Earthquake Motion.*

In the introduction to this paper three important results which have been obtained have already been enumerated. (see p. 5.)

The majority of the earthquakes which have been registered have consisted of a series of irregular vibrations usually lasting over a period of from 20 to 60 seconds. What I should call a complete earthquake is illustrated in Fig. 58. In this diagram we observe that the disturbance consisted of three parts. First there was a series of exceedingly small vibrations having a quick period. Next came a sudden motion of large amplitude constituting the shock of the earthquake, and lastly a long series of motions irregular both in period and amplitude. A marked character in many earthquakes has been that these latter motions died out with a decreasing period.

In the diagram referred to, the preliminary tremors are visible over a period of almost 12 seconds. There appears to have been from 5 to 6 complete vibrations per second. Had the instrument been sensible to waves of a smaller amplitude, it is probable that the duration of the preliminary tremors would have been increased still more. From a consideration of diagrams like this, it is also probable that the actual commencement of a disturbance has never yet been recorded. Might we not therefore ask the question whether this unrecorded portion of an earthquake has not been made known to us by the sound phenomena which often precede large earthquakes? The nearer we are to the commencement of an earthquake the quicker are the vibrations, and we have only to reduce the period of vibrations already recorded, one third, to be within the limit of vibrations sufficiently rapid to produce in the air a disturbance which might be audible.

The amplitude of the shock or shocks which an earthquake may contain, usually varies between 1 and 10 millimeters, the maximum motion in ordinary earthquakes where there is no well defined shock usually being from .1 to 1<sup>mm</sup>.

In several cases the greatest motion of shock appears to have been inwards or towards the origin of the shock. One



characteristic of the shock of an earthquake is, that it has a definite direction which may be recorded over a large area, whilst the other motions of an earthquake, in fact all the motions of an ordinary earthquake, are movements which continually change in direction and may be very different even at two neighbouring stations.

In other words we may say, that the direction of vibration of the ground in an ordinary earthquake has usually no immediate relation with its direction of propagation.

The maximum acceleration during these movements of shock may reach as much as 500<sup>mm</sup> per second per second. Ordinary earthquakes have maximum accelerations of from 10 to 100<sup>mm</sup> per second per second.<sup>(1)</sup> A motion like the former is on the verge of being destructive and brick chimneys may be cracked. These calculations are based on the assumption that the motion is like that of an ordinary pendulum. Hitherto the records have been drawn on plates which move too slowly to sufficiently spread out the waves of shock. In consequence of this it has not been possible to make the necessary time measurements enabling us to calculate maximum accelerations without making assumptions as to the nature of the motion. Here and there, where I have attempted to make such calculations, it will be observed that the results obtained are very much lower than any of the results obtained where simple harmonic motion has been assumed.

I may mention that I am now endeavouring to obtain records of earthquakes on rapidly moving plates.

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<sup>(1)</sup> *The above accelerations are calculated on the assumption that*  

$$a = \frac{V^2}{a} \text{ where, -}$$

$a$  = maximum acceleration.

$V$  = maximum velocity.

$a$  = amplitude or half a semioscillation.

*The intensity of an earthquake or its power of overturning and shattering objects may also be represented by the quantity  $\frac{V}{t}$ , where,—*

$V$  = the maximum velocity

$t$  = the quarter period.

*The power of projection will be measured by  $V$ . These questions are more fully discussed in my next paper to the Society on "Seismic Experiments."*

Prof. Alexander suggested to me that it is not improbable that the portion of an earthquake which I have called the shock, may have been executed so rapidly that the rocks in which this disturbance took place had not time for elastic yielding. There was in fact a sudden "push". The portion of the area thus affected might be called the core of the earthquake. If such a condition as this exists, we have in it a means of explaining the enormously high velocities of propagation which have sometimes been recorded.

Lastly we come to the resulting tremors which are irregular in period in amplitude and in direction. These resulting tremors of a large disturbance are identical in character with the collection of vibrations which constitute an ordinary earthquake. They usually vary in period from .2 to 1 second, but I have noted them with a period of 2 or 3 seconds. These latter waves die out so slowly that they are seldom felt, and if an instrument is not very sensitive they may not be recorded. They may however be seen in the slow oscillations of the bubble of a delicate level long after all sensible motion has ceased. That these motions are not due to the inertia of the liquid in a level, may be easily verified by suddenly tipping a level and it will then be seen how quickly the bubble returns to rest.

The end of an earthquake like its commencement is therefore an indefinite point.

This leads me to consider the duration of an earthquake. Earthquakes in Japan are usually felt over a period of from 20 to 60 seconds, but I have mentioned instances where records have been traced over  $4\frac{1}{2}$  minutes. Had the instruments which gave these records had sufficient multiplication to record all the small motions at the commencement of the disturbance, and had they been sufficiently frictionless to record the slow pulse-like motion at the end of disturbance, it is probable that the duration of the earthquakes recorded would have been very much greater than that here given. *Strictly speaking we do not yet know the duration of an earthquake.*

With regard to the velocity at which an earthquake may be propagated, I have sometimes obtained results indicating this quantity to be several hundreds of feet per second, and sometimes several thousands. It must however be remarked that although the means I have had for these determinations are equally as good as any hitherto employed, they are nevertheless open to so many errors that the results yet obtained must be allowed to stand over for farther confirmation

The general conclusions towards which these results point are as follows:—

1. Different earthquakes have travelled across the same area with different velocities
2. The greater the initial disturbance the greater has been the recorded velocity.
3. The same disturbance spreading from its origin is propagated with a decreasing velocity.