EARTH TREMORS IN CENTRAL JAPAN.

RECORDED BY AN AUTOMATIC TREMOR MEASURER.

By John Milne.

[Read November 18th, 1886.]

INTRODUCTION.

In 1883 I read before the Seismological Society a paper on Earth Tremors, in which I gave an outline of what had been done towards the study of these movements, not only in Japan, but also in other parts of the world. (See Trans. Seis. Soc. Vol. VII., Part I.) In that paper a description was given of the various instruments which had been used for the observation of earth tremors, especially those employed by the observers in Italy. One instrument which was described in detail was the normal tromometer of Bertelli and Rossi. Among the more important results which have been obtained in connection with microseismical disturbances is the observation that they are closely connected with barometrical fluctuations. Those move ments which take place with a barometrical depression, which are the movements most generally observed, are called *baro-seismic* movements, while those agreeing with periods of high pressure are called *volcano-seismic* movements. The relation of micro-seismic storms to barometric pressure is very marked during volcanic eruptions. Professor M. S. de Rossi, the indefatigable

noticeable in winter. Vertical movements are connected with seismic desturbances. In addition to these observations a number of other observations of less importance have been made, an account of which may be found in the above mentioned paper.

For translation of the information I have derived from Italian sources I have to thank my friend, Signor Luigi Casati, of the Italian Legation.

The subjects which are treated upon in the following pages are as follows :—

I.—Recent work in Italy.

II.—Observations on the work done in Italy.

III.—Tremor recorders, with special reference to an automatic tromometer.

IV.—Tables of records made with automatic tromometers.

a. General barometric analysis of these records.

b. General wind analysis of these records.

c. Detailed wind analysis.

d. Detailed barometric analysis.

e. On the presence of tremors and absence of wind.

f. On the absence of tremors and presence of wind.

g. Analysis of a few selected tremor storms.

h. Tremors and earthquakes.

i. Tremors and the state of the wind in central Japan in 1885.

V.—Earth tremors on mountains.

VI.—General conclusions.

I.—RECENT WORK IN ITALY.

In consequence of the efforts of Professor M. S. de Rossi, the observation of microseismical movements in conjunction with the observation of other terrestrial phenomena has been systematized throughout Italy. In 1883, with the assistance of the Minister of Agriculture and Commerce, a central observatory for these observations was established under the directorship of Professor Rossi in Rome.

At this observatory every day a map of the Italian Peninsula is drawn, on which are indicated the following phenomena :—

1. Isobars at one millimeter apart.
2. The intensity of microseismic movement in different parts of the kingdom.
3. The number and intensity of earthquakes.
4. The state of activity at volcanoes.
5. The state of hot-springs.
6. The increase or decrease in the waters of wells.

With each map information respecting the above phonomena as observed at special places is given in detail.

These maps are issued in series of ten, a number corresponding to Rossi's microseismic periods.

The information on which the maps are founded is obtained from 27 stations distributed throughout the kingdom, at each of which there are at least instruments for recording earth tremors.

From the tabular matter accompanying the maps you can read the state of microseismic activity at any particular station or the average state of activity for the whole kingdom for any particular day or for a whole decade of ten days.

In the *Bullettino del Vulcanismo Italiano,* Professor Rossi gives a ten days' summary as to the state of endogenous phenomena throughout the kingdom.

The following are examples of such summaries from January to May, 1885 :—

JANUARY—1885.

1. Decade.—During this period seismic activity was very marked in Andalusia. As there was also considerable activity in Italy, Rossi named this period the Italo-Iberico. In Italy the microseismic disturbances were strong, and invariably accompanied seismic maxima which occurred on the 1st, 5th, and 8th. The barometric pressure, which was always high, did not seem to disturb this activity.

2. Decade.—The whole of this period is marked by a strong atmospheric disturbance, which increased the microseismic activity throughout the whole of Italy. Earthquakes were doubled in number and also in intensity, the maxima of disturbance being on the 12th, 14th, 17th, 19th, and 20th. These dates, when we reckon according to decades, nearly correspond to the dates of maxima in the first decade.

3. Decade.—The centre of barometric depression was felt on the 21st, 23rd, and 26th, which dates coincide with important microseismic disturbances. These disturbance have been accompanied or preceded by earthquakes which were more numerous than severe—the number recorded being 100. The largest groups appeared on the 21st-22nd, the 24th-28th and the 31st. These maxima occur at intervals relatively to those which preceded them which are decadic.

February.

1. Decade.—On the 3rd, 4th, 5th, 6th and 10th the geodynamic and atmospheric disturbances were coincident. On these days the centre of barometrical depression was in Italy. Microseismic movements were observed and a number of earthquakes were felt. Neither the microseismic disturbances nor the earthquakes were excessive. The seismic maxima were on the 3rd and 4th, and again on the 10th, when an earthquake in Liguria was felt.

2. Decade.—The strength and number of endogenous phenomena diminish towards the end of the decade. The centre of atmospheric depression occurs on the 11th, 18th, and 20th and is accompanied by microseismic activity. The earthquakes were not numerous nor severe. They occur on the 12th and 13th after the microseismic disturbance, and again on the 16th, usually shaking the coast of Liguria.

3. Decade.—After the atmospheric depression and microseismic movement on the 20th there occurred a seismic maximum on the 21st, with earthquakes along the whole peninsula on

the Alps, the Apennines, and in Sicily. After this there were no important disturbances either in the atmosphere or in the earth. In fact an unusual calm took place which, as experience has taught, was the precursor of unusual activity. This commenced on the 26th and continued on the succeeding days when the Appenines (Modena) and the Baldo region near Verona were shaken by a large and strong earthquake. The seismic disturbances of this decade therefore kept at the same periodic distance as in the previous decade, the movements of the 21st corresponding to the movoments of the 10th, and those of the 26th to those of the 16th.

MARCH.

1. Decade.—The seismic period commenced in Emilia on the 20th February, continuing on into March, especially in the first decade. It showed the usual relations with other phenomena.

On March 1st a maximum coincides with the centre of a barometric depression. On the 3rd a maximum occurs without showing this coincidence, but on the 6th and 7th the coincidence is again noted. With this last maximum microseismic activity considerably increased, which activity continued into the second decade.

During this decade the eruptive phenomena of Stromboli were very marked.

2. Decade.—Strong microseismic movements continue until they unite with actual earthquakes. This is noticeable with the earthquakes of Emilia and Sicily on the 12th and 14th, when there was a new atmospheric tempest. With similar atmospheric conditions we have new microseismic and seismic disturbances on the 19th and 20th. These especially shook the Province of Verona and Sicily.

3. Decade.—The maxima of general activity are not well distinguished in this decade. However, between the 21st and 26th Italy was the centre of an atmospheric depression with

which there was seismic and microseismic activity. These movements, however, momentarily ceased because they accompanied the strong winds between the 28th and 30th. The activity of Vesuvius appears to have coincided with the general maximum just discribed.

APRIL.

1. Decade.—The endogenous activity continues as on the third decade of the previous month. All days are maxima, but the greatest disturbances were on the 3rd, 4th, 5th, 7th, 9th, and 10th, and in each case there was a barometric depression. The great earthquake of the 10th appears to have been the culmination of this storm.

2. Decade.—Earthquakes diminish in number and force and with them earth tremors also decrease.

The points of maxima are from the 11th to the 13th, the 16th to the 18th, and between the 19th and 20th. An atmospheric depression accompanies the two first of these maxima, but it is not noted with the last, which, it may be remarked, is the least of the maxima.

Decade. 3.—Endogenous activity continues to decrease until the 28th, which was a day without any earthquakes. The maxima, which are small, occur at the usual intervals in the 21st, 23rd, 24th, 25th, 27th, and 29th.

Out of them the most important microseismic movements took place on the 27th, 29th, and 30th and with these movevents there were atmospheric depressions. Vesuvius was relatively quiet during the first fortnight, but during the second, especially from the 20th, it emitted some small streams of lava.

MAY.

Decade 1.—Amongst the more important phenomena in this decade was a slight eruption of Vesuvius. Seismic maxima appeared on the 1st, from the 3rd to 5th, and on the 8th. The microseismic movements continued from the 1st to the 7th, with maxima on the 5th and 7th. These were connected with atmospheric depressions.

Decade 2.—There was an important microseismic movement on the 12th, together with a depression. Afterwards they continued from the 4th to the 19th, especially on the 15th and 19th, at which time (except the 17th and 18th) there was an atmospheric depression either in Italy or near. Earthquakes were numerous but slight. Etna was shaken. Their maxima were from the 11th to the 14th, and the 18th to the 20th.

Decade 3.—In this decade seismic and microseismic repose commences. Atmospheric depressions are few. On the 22nd a slight depression was accompanied by microseismic disturbance, the only activity during this calm. A few slight shocks had thus maxima on the 21st, 28th, and 30th, keeping an interval of the double decadic period.

II.—OBSERVATIONS ON ITALIAN WORK.

In connection with the work now being carried out in Italy, there are several points which I find difficulty in understanding. One difficulty arises when I compare the maps and the data on which they were founded with Professor Rossi's general conclusions which have just been given.

For instances the average values for the microseismic activity in the Italian Peninsula for the month of January, 1885, is given in the *Bullettino del Vulcanismo Italiano* (Anno XIII. Fas. 1—3, p. 5, 6 and 7) as follows:—

JANUARY 1885.

Days. Decade I.	1*	2	3	4	5*	6	7	8*	9	10	
Med. Micros.	1.42	2.23	2.32	1.68	1.77	2.26	1.70	1.63	1.33	0.61	
No. of Shocks	4	3	3	3	4	3	3	2	3	4	
Max. Intensity	5°	4°	3°	1°	4°	1°	2°	3°	1°	1°	
Days. Decade II.	11	12*	13	14*	15	16	17*	18	19*	20*	
Med. Micros.	1.44	3.07	2.59	2.15	3.07	2.86	2.41	2.08	3.37	2.59	
No. of Shocks	3	7	3	17	6	9	5	3	10	8	
Max. Intensity	2°	3°	1°	3°	3°	1°	1°	1°	3°	2°	
Days. Decade III.	21*	22*	23	24*	25	26	27	28*	29	30	31*
Med. Micros.	2.03	2.13	1.74	2.66	1.59	1.83	1.74	.94	.64	.66	1.35
No. of Shocks	19	4	4	14	19	16	9	6	1	2	6
Max. Intensity	1°	3	1	8	1	1	1	1	1	2	3

When examining the above table I fail to see that the days marked with an asterisk, which Professor Rossi mentions as days

of maximum activity, are really such days. Even if they are such days, then the days of maximum activity hardly appear to agree decadically with those of another decade. When each decade is divided into three parts, if there is not actual correspondence it seems impossible that there should not be a near correspondence.

My chief object in making these criticisms is for the purpose of gaining information, and I therefore trust that they will be accepted in that spirit. As matters stand at present, with the same data that has been employed by Professor Rossi, although I might agree with him on many points, I do not see how I could fail but arrive at different results regarding the particular points now discussed.

Another point to which I would draw attention is the oft-repeated statement that microseismic storms accompany barometric depressions. I have repeatedly observed the same fact in Japan, but I have also observed that tremors sometimes occur with a high barometer.

A more general way of connecting tremors with atmospheric phenomena appears to be to regard the majority of them as committant with steep barometric gradients, and a glance at the following table, compiled from tables in the *Bullettino del Vulcanismo Italiano* apparently shows *that tremors are at a maximum in the Italian peninsula when the barometrical gradient is steep, no matter whether the barometer is high or whether it is low.*

Date. 1885.	Mean Microseis. Intensity in Italy.	Barometric Fall per 300 Geog. Miles.	Heights of Bar. 300 Miles Apart + 700.
Jan. 1	1.48	7	63—70
Jan. 2	2.24	6	63—69
Jan. 3	2.47	6	64—70
Jan. 5	1.84	4	64—68
Jan. 6	2.29	4	64—68
Jan. 7	1.89	4	63—67
Jan. 10	.53	1	64—65
Jan. 12	3.59	7	48—55
Jan. 13	3.03	6	44—50
Jan. 19	3.75	9	61—70
Jan. 20	2.79	10	54—64
Jan. 30	.75	3	63—66
Feb. 3	2.80	9	54—63
Feb. 7	1.13	4	60—64
Feb. 15	.43	0 or 1	67—68
Feb. 16	.57	2	67—69
Feb. 23	.98	3	65—68
Feb. 24	.82	3	69—72
Feb. 27	.73	3	65—68
March 2	.88	1	59—60
March 3	.71	1	62—63
March 6	4.37	8	53—61
March 7	4.04	8	54—62
March 14	3.14	8	58—66
March 16	.57	1	72—73
March 17	.49	0	72—72
March 20	1.14	4	51—55
March 22	1.09	4	54—58
March 29	.82	0	59—59
March 30	.81	3.5	56—58.5
March 31	.96	2	61—63
April 2	.54	1	58—59

The above series of days have been chosen as being days on which there have either been very many tremors or very few. From an inspection of the table it will be seen that a low barometer, as far example on March 29th, is not necessarily ac-

companied with unusual tremors and that tremors only occur when the barometrical gradient is steep.

A steep barometrical gradient is usually accompanied by wind, but unfortunately the means of comparing the microseismical disturbances with the state of the wind have not been given. While here suggesting that some of the microseismical disturbances recorded in the *Bullettino del Vulcanismo Italiano* may be due to the action of the wind producing a general disturbance on the surface of the earth, I fully recognize that there are particular phenomena connected with microseismical disturbance which are difficult to reconcile with such an explanation.

One remarkable instance where tremors have accompanied earthquakes was on the 26th February.

III.—TREMOR MEASURERS.

Among the first instruments I employed were microphones, in conjunction with telephones and delicately-suspended short-period light pendulums. From time to time the telephones emitted strange sounds. As to what was the cause of these noises I am unable to say. Unless you kept your ear continually at the telephone there did not appear to be any method of obtaining a satisfactory record, so that, after much labour, these instruments were eventually discarded. For very similar reasons the small pendulums, which were often in a state of tremor, were also discarded.

The next class of instrument which I employed was similar to an apparatus suggested by Sir William Thomson, and used by George and Horace Darwin in the Cavendish Laboratory when experimenting on the lunar disturbance of gravity. Any one who has read Mr. Darwin's account of these experiments will recognise the unusually great care which is required by any one who undertakes to make observations with such instruments. As I was without either assistants or a laboratory, and as my instruments were of the roughest description, my at-

tempts at making satisfactory observations altogether failed. I certainly saw that the spots of light were continually shifting in position, but whether this was due to a tip of the soil or simply to contractions and expansions in portions of my instrument, I was unable to determine.

After much trouble and considerable expense, I very reluctantly gave up the pendulums and mirrors, and sought for apparatus of a still simpler kind. Having accidentally read an account of Plantamour's observations with levels, the simplicity of the apparatus induced me to borrow a pair of astronomical levels from the Imperial Observatory and follow his example. For a long time these levels were installed beneath cases on a column kindly lent to me by the Professor of Natural Philosophy in the Imperial College of Engineering. Here they remained for over a year, after which they made many journeys. At one time they were nearly 13,000 feet above sea-level on the top of the conical Fujisan. At another time they were some hundreds of feet below sea-level at the bottom of the Takashima Mine. These observations attracted the attention of the authorities at the Imperial Observatory, who, recognising the bearing they might have upon work which was going on in the Observatory, supplemented my observations with a second set of levels. All the usual precautions were taken to guard against the effects of temperature, and observations were carried out every three hours, both day and night, for more than a year. As the books of records accumulated, and the curves grew until some of them were 30 to 40 feet in length, experience showed that the errors chiefly due to changes in temperature might be equal to and even exceed the effects which were being sought. Now, I am inclined to an opinion communicated to me in a letter from M. d'Abbadie, who remarked that two levels upon the same column might be parallel, and yet their bubbles might move in opposite directions. Notwithstanding this, the observations of levels have led to some interesting results.

First, there is the fact that level bubbles may wander without there necessarily being a change of level. Second, that level

bubbles continue to move long after the sensible motion of an earthquake has ceased, thus giving us a means of observing the movements of long periods which usually bring the phenomenon of an earthquake to a close. After the earthquake the bubble will sometimes take up a position slightly different to that which it had before. Changes in the position of bubbles have been observed a short time before some of our earthquakes. Another result is the fact that the greatest irregularities in the curves showing the position of the bubbles of a level occur when earthquakes are most numerous. This is during the winter months. A last result is the fact that during a typhoon, or when the barometer is unusually low and fluctuating, a level bubble may be distinctly seen to pulsate through a small range, as if there were continuous changes of level going on.

While working with the levels, another kind of instrument which I employed was a pendulum, suspended from an iron stand, and so arranged that its stile could be viewed in the field of a microscope. By placing a prism beneath the end of the stile, the image of its end could be looked at horizontally, and the motion of the pendulum could be seen in any azimuth. At first I employed two microscopes placed at right angles, but by the adoption of the prism one microscope became sufficient. With these instruments, which are similar to those employed by Messsrs. Bertelli, M. Rossi, and other Italian observers, I verified for myself some of the more important results which had been noted in Europe.

For instance, it was seen that the pendulum was seldom at rest. Storms of tremors would take place with a low barometer. The pendulum did not always vibrate over the same point. It appeared as if there had been a tip in the soil, and the stand of the apparatus had been slightly inclined. These, together with other results which in many respects are little more than repetitions of results obtained by Bertelli, Rossi, and other observers, I have already published. Without attempting to describe other experiments which I have instituted, I will now

give a brief description of an instrument which has been reached gradually, and which has given me the greatest satisfaction. From a letter received from M. d'Abbadie, whose researches regarding the change of vertical are amongst the most important yet instituted, I learn that my instrument has many points in common with one employed by M. Bouquet de la Grye. When I first set up this instrument, it was simply as a contrivance intended to make electrical contact, and set certain machines in action at the time of an earthquake. I next employed it as an instrument to record the occurrence of slight earthquakes. In its third form it was used to indicate earth-tremors and deviations in the vertical. It will be readily understood from the accompanying sketches, Figs. 1 and 2: AA is a circular disk of cast iron about $\frac{3}{4}$ inches in thickness, resting on levelling screws. Bolted to this is a tripod of angle iron about 5 feet high, BB. This forms the support for a pendulum, C. The bob of this pendulum weighs about 7 lbs. It is made of a brass tube (3m. diameter and $2\frac{1}{2}$ m. long) filled with lead. This is carried by a fine iron wire 3 feet $3\frac{1}{4}$ inches long, soldered into a small hole in a plate at the top of the tripod. A spike, C, projects from the base of the bob (see Fig. 3). As the bob with its spike were turned in a lathe, the end of the spike, the point of support, and the centre of figure of the bob are fairly in a straight line. A long, light pointer, D, made of a strip of bamboo which has been varnished, is kept in contact with the base of the pointer, as shown in Fig. 3. At the top of the pointer there is a light brass ring, *e*; at the top of this there are two fine needle-points, *a* and *b*. The point *a* is kept in contact with the base of the pendulum by turning the screw T, which raises the flat springs on which *b* rests. T is carried by a strong stand, E, which rests at three points on A; *f f* is a disk of lead which is nearly equal in weight to that of the pointer below *b*.

In one instrument *a b* is 6 mm., while the total length of D is 415 mm. With these dimensions we may suppose that if the base pendulum moved, say, 1 mm., then the lower end of the pointer would move about 70 mm. The values to be given to

the defections observed in the pointer have also been estimated by giving a slight turn to one of the levelling screws of the base plate, and thus tipping the plate through a known angle. Records were at first made by reading a scale of millimetres placed beneath the end of the pointer. Experience showed this method to be inconvenient and without satisfaction. What occurred between the hours of observation was unknown, whilst the records which were made were liable to greater or less errors due to the observer. This led me to seek for some method which would render the observations automatic. To attach a hair to the end of the pointer and let it be dragged across the surface of a smoked glass created too great friction. The necessary appliances for photographic registration were too costly, and too troublesome to be employed as I was situated in Japan. A very near approximation to frictionless registration was obtained by sending a current down the pointer, the end of which trailed on the surface of a thick film of iodised starch covering a strip of paper. The strip of paper, which was on a metal tray, moved slowly by clockwork beneath the lower end of the pointer. On taking out the paper I found that the film of starch, with its blue line could be dried down to form a brown line on the paper. The process was troublesome and the line subject to distortion by the flow of the starch. The next idea was to discharge a spark from the end of the pointer and perforate a band of paper moving beneath the end of the pointer at the distance of about 1 mm. This feature in the apparatus, M. d'Abbadie writes me, is an essential feature in the apparatus of M. Bouquet de la Grye. To avoid losing a record, should the pointer move parallel to the length of the paper, two bands of paper, *gg*, moving at right angles (by means of the clock, H), are employed (Fig. 2). One band passes beneath the other over the surface of a brass plate, *h*. The paper used is the ordinary paper employed in a Morse telegraph instrument. By allowing the hand of a clock to pass every five minutes across a wire the current from two of Thomson's tray-cells is sent through an induction coil which yields the sparks to perforate the paper.

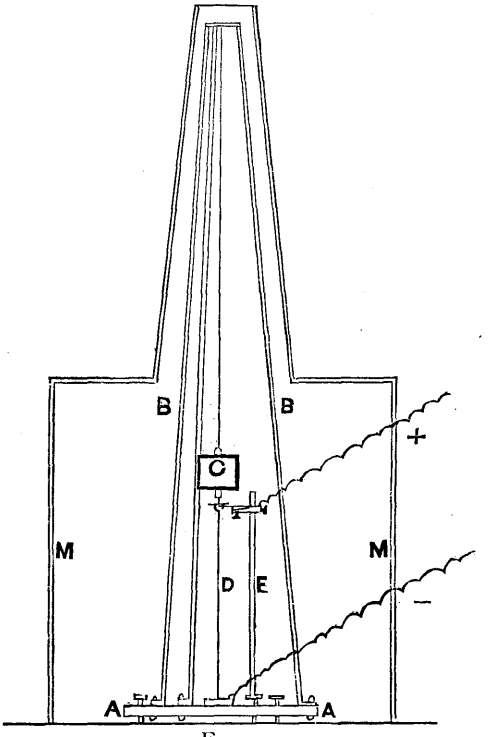


FIG. 1.

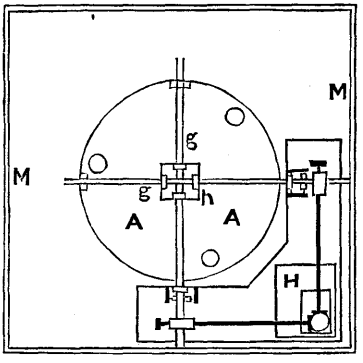


FIG. 2.

Every hour the hand of the clock makes a long contact by passing across a small strip of platinum. In this way a large hole is made in the moving bands of paper and the hours are recorded.

To secure myself against error, the same secondary current which perforates the paper of one machine is carried by wires to perforate the paper of a second instrument of slightly different construction placed on a stone column in a distant room.

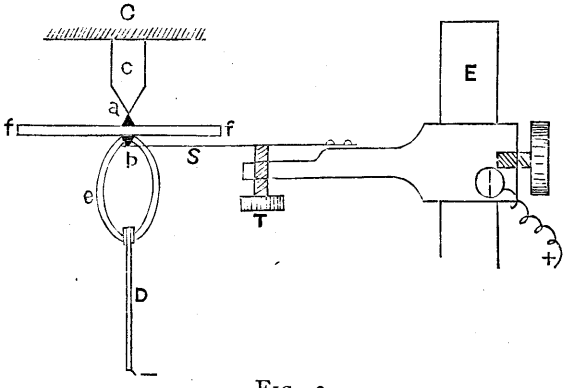


FIG. 3.

The only work required is to wind the clock which pulls the paper and the clock which makes the contacts. This being done, records are automatically made every five minutes.

The character of the records are as follows :—

1. Sometimes for days the pointers remain stationary, as is indicated by the sparks being regular and in a straight line (see Fig. 4).

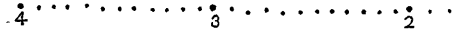
2. Sometimes the pointers are in a state of tremor, and the sparks perforate the paper at many points, giving a line of several millimetres in breadth (see Fig. 5). These tremors may continue for ten or twelve hours. From the diagram, the duration of these tremors and the range of motion can be accurately measured. The instruments in both rooms agree as to the occurrence of tremors and periods of rest.

3. Sometimes the pointer will slowly wander from the straight line, and then slowly return. This usually takes place two or three times in succession. It would seem as if the ground had been slowly tipped through one or two seconds of arc, the period of each tip being from fifteen to sixty minutes (Fig. 6).

In regard to the occurrence of the tips, the instruments in the two rooms only occasionally coincide.

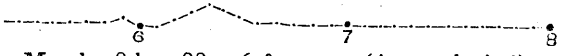
As to whether they are really to be regarded as true disturbances of level, or simply as movements due to local causes, I shall be better able to speak after a more careful examination of the records.

4. Sometimes I find the bands of paper perforated over their whole breadth by sparks in all directions. This indicates that an earthquake has occurred and the pointer has been swinging (see Fig. 5, about 9.15 p.m.). All these figures have been produced by pricking through from the original diagrams.



February 25th, 2-4 A.M. (No movement)

FIG. 4.



March 28th, 1885, 6 & 7 P.M. (An earth tip?)

FIG. 6.

March 16th, 1885, 8-10 P.M. (Tremors & Earthquake)

FIG. 5.

The clocks which I have used are made from small American spring clocks, costing in Japan about 12*s.* each. The total cost of the portion of the apparatus figured, including the case, M, the doors of which and the parts which come in contact with the column are edged with flannel, is about 25 *yen*, or £4 10*s.* In Europe an instrument of better construction would cost more. One of the columns on which an instrument is

placed measures 6 feet × 3 feet and 5 feet high. It is constructed of brick and rests on concrete. The other column, which also rests on concrete, is made of stone. It measures 2 feet 2 inches × 2 feet 2 inches and is also 5 feet in height.

This latter column is rather too slight, as I find that even the pressure of my thumb upon it is sufficient to cause the pointer of the instrument to move several millimetres.

Amongst those who may possibly have a practical interest in this matter are those who have to deal with mines—especially, perhaps, coal mines.

In the columns of the *Japan Gazette*, in *Nature*, in the *Mining Journal*, and other papers, references have been made to the attempt to observe earth-tremors and other phenomena in the Takashima Colliery near Nagasaki. At the conclusion of a report to the British Association, 1884, on the earthquakes of Japan, a letter from Mr. John Stoddart, the chief engineer of that mine, tells us that, owing to the working of the mine and other causes, he finds it impossible to make observations with delicate instruments. He therefore proposes to move the instruments to some distant station, assuming that any natural cause which would cause tremors in the mine will be generally felt over a considerable area. As to whether there is a connection between earth-tremors and the escape of gas in collieries, we do not yet know. Mr. Walter Browne, in a paper to the North of England Institute of Mining and Mechanical Engineers, thinks it desirable that investigations on this subject ought to be made, and quotes what is being done at Takashima. Mr. Galloway, writing in *Nature* of February 5, if I read him correctly, does not encourage Mr. Browne's suggestions, and enters into an argument about the possibility of an earth-tremor forming a fissure. Earthquakes often form fissures on the surface, but their effects in mines are usually nothing. I make this statement on the authority of personal inquiry in many mining districts.

With the exception of the disturbances near an epicentrum, the movements due to ordinary earthquakes are so superficial

that the range of motion at the depth of 10 feet is sometimes only one-fortieth of what it is at the surface. Earth-tremors are phenomena usually lasting many hours, and they certainly occur with low barometers. That they could by any possibility form fissures it is difficult to imagine.

IV.—OBSERVATIONS WITH AN AUTOMATIC TROMOMETER.

These observations, with a few omissions, extend from January 13th, 1885, to May 14th, 1886.

The north and south component was recorded on the band of paper running east and west; the east and west component being recorded on the paper running north and south.

By a record being "wavy" it is meant that the line of dots followed each other in regular succession so far as time is concerned, but that alternate dots now and then deviated from .5 to 1 mm. to the right or left of the central line. A wave indicated in the form of a fraction, as $\frac{3.}{30\text{-}40}$ means that the wave as shown in the record had an amplitude of 3 mm. while its period was from 30 to 40 minutes. Trems. or small trems. mean that there were tremors forming a band of from .5 to 1 mm. broad.

The earthquakes are those recorded at the Imperial Observatory about 2 miles distant. *a* and *b* respectively mean a.m. and p.m. The intensity of many of the earthquakes is recorded in degrees and minutes.

From June these intensities are recorded in absolute measures—thus $\frac{1.6}{2.7}$ means that the amplitude or half semi-oscillation of the largest wave was 1.6 mm. and its period 2.7 sec.

The barometric readings are the mean readings in millimeters for 24 hours.

The column relating to wind gives the velocity in kilometers for 24 hours. As an approximation to the popular terms used

in expressing the force of wind, Mr. E. Knipping tells me that I may consider—

A light breeze as anything up to 200 kilometers per 24 hours.
A moderate to strong breeze from 200 to 400 kilometers per 24 hours.
Gales and heavy gales from 400 kilometers per 24 hours and upwards.

For the meteorological data published in the tables I am indebted to the director of the Meteorological Observatory in Tokio.

For 1886 the state of the wind at Tokio together with the barometric gradient are given for each day in the form of three fractions. These three fractions respectively refer to observations made at 6 a.m., 2 p.m., and 9 p.m. The numerator of a fraction indicates the intensity of the wind as expressed in the tri-daily weather maps issued by the Meteorological Department; the denominator indicates in millimeters per 120 geographical miles the barometric gradient as directly measured from the same maps. The meanings of the wind intensities are as follows:—

0 = calm = 0—1.5 meters per second.
1 = light = 1.5—3.5 meters per second.
2 = moderate = 3.5—6 meters per second.
3 = strong = 6—10 meters per second.
4 = gale = 10—15 meters per second.
5 = heavy gale = 15—29 meters per second.
6 = hurricane = 29—104 or more meters per second.

These intensities are also used in the records for 1885. W means that there was wind of greater intensity than 2 blowing at several stations in Central Japan. WT3 or WT4 means that there was a *local* wind at Tokio of 3 or 4; at other places it being practically calm. (See Maps referring to records from March 15th to March 19th.)

1885.

	North-South Component.	East-West Component.	Earthquakes.	Barometer reduced 0° C. at sea level +700.	24 hours velocity of wind.	Wind in Central Japan at			Remarks.
Jan.					Killo.	6 a.m.	2 p.m.	9 p.m.	
1	... ...	... ...	... ...	64.6	169.1	...	...	...	
2	... ...	... ...	... ...	58.9	222.0	...	...	...	
3	... ...	... ...	2.31.53 a. 3°	60.1	524.4	...	...	...	
4	... ...	... ...	... ...	67.2	320.3	...	...	...	
5	... ...	... ...	... ...	67.2	218.6	...	...	...	
6	... ...	... ...	... ...	65.6	312.0	...	...	...	
7	... ...	... ...	... ...	66.2	401.4	...	...	...	
8	... ...	... ...	10.27.45 a. 45′	59.8	474.2	...	...	...	
9	... ...	... ...	... ...	65.0	456.6	...	...	...	
10	... ...	... ...	... ...	68.4	209.5	...	...	...	
11	... ...	... ...	... ...	59.3	235.7	...	...	...	
12	... ...	... ...	... ...	58.1	473.7	...	...	...	
13	Record irregular.	... ...	... ...	66.2	382.9	...	...	...	
14	... ...	... ...	... ...	65.7	188.2	...	...	...	
15	... ...	Wavy.	After 9 p.	60.2	377.4	...	...	...	
16	Two small waves. No trems.	Wavy.	... ...	66.0	238.8	0	0	0	
17	A few small waves.	Wavy.	10.13.39 a. 1° 11.20.41 p. 2°	60.6	160.3	0	0	0	
18	Two 4mm. waves.	... ...	... ...	60.1	229.6	0	0	0	Bar. low to East.

	North-South Component.	East-West Component.	Earthquakes.	Barometer reduced 0° C. at sea level +700.	24 hours velocity of wind.	Wind in Central Japan at			Remarks.
						6 a.m.	2 p.m.	9 p.m.	
Jan.					Killo.				
19	... ...	At 11.30 p. small wave.	... ...	58.9	214.7	0	0	0	All day bar. low over Tokio or to East.
20	... ...	... ...	... ...	64.3	468.0	WT4	WT3	0	
21	Small Trems. 10.30 p. to	... ...	3.0.0. p. small.	67.0	180.1	0	0	0	
22	5 a. again from 11 p. to	Trems. from 11 p. to	... ...	62.4	257.8	0	W	W	
23	4 a. At 3 p. two waves $\frac{3}{30}\frac{}{40}$	3 a.	... ...	66.0	404.8	0	WT3	0	
24	At 12 noon deflection off paper.	... ...	9.20.4 a. 3° 40′	70.6	243.2	0	0	0	
25	From 12 noon small waves with 5″-10″ period.	Wavy. At 7, 8, & 9 p. Very wavy. There are 7 waves of $\frac{1}{10}$	... ...	61.3	225.1	0	0	0	
26	... ...	Wavy until 1 p.	... ...	59.0	586.2	WT3	WT3	0	
27	... ...	11 to 12 p. slight waves.	... ...	60.7	222.0	0	0	0	
28	Wavy. At 6 p. two waves $\frac{4}{30}$	Wavy from 12 to 6 p. Also from 9-11 p.	... ...	64.5	658.5	WT3	W	WT3	
29	... ...	... ...	10.0.0 p.	69.0	334.2	0	WT3	0	

30	... ...	... ...	... ...	71.8	354.3	0	WT_3	0	
31	... ...	... ...	11.54.8 p. 2° 10′	72.6	193.0	0	0	0	
Feb.									
1	Small trems.	... ...	2.15 and 5 a.	64.7	248.6	0	0	WT_3	
2	Small trems.	... ...	4.8.11 p. 10°	63.4	357.5	WT_3	0	0	
3	... ...	... ...	... ...	59.4	331.4	0	WT_3	0	
4	... ...	... ...	7.52.7 p. 2° 10′	61.8	264.1	0	0	0	
5	... ...	... ...	... ...	62.7	238.4	0	0	0	
6	... ...	... ...	9.40.27 a. 0° 30′ 1.34.57 p. 10° 40′	59.9	454.9	0	WT_3	WT_4	
7	... ...	... ...	... ...	64.1	513.6	WT_3	WT_3	0	
8	Trems. from noon to	Wavy from 4 a, to 7 a.	... ...	62.0	321.3	0	0	0	No unusual Bar. gradient.
9	2 a.	... ...	2.03.40 a. 4° 20′	57.7	285.4	0	0	0	At 6 a. and 2 p. low Bar. to the South.
10	... ...	... ...	... ...	61.9	305.6	0	0	0	
11	... ...	... ...	... ...	61.0	431.5	0	WT_3	WT_3	
12	... ...	Slight wave $\frac{1}{30}$	2.56.58 p. 10° 0′	60.0	549.8	0	W	W	
13	Small waves.	Small waves at 7.30, 9.30, and 10.15. Small waves at 1.45 a. and others until 8 a.	... ...	63.0	786.1	W	0	0	
14	Small waves.	At 1 a. wavy.	... ...	64.3	237.9	0	0	0	
15	... ...	... ...	... ...	59.5	294.0	0	0	W	
16	... ...	1.45 slight wave and on to 4 p.	... ...	60.4	538.3	0	W	WT_3	
17	... ...	... ...	... ...	59.3	188.5	0	0	W	At 9 p. wind at To-
18	... ...	... ...	... ...	56.5	384.1	W	0	W	[kio=0.

	North-South Component.	East-West Component.	Earthquakes.	Barometer reduced 0° C. at sea level +700.	24 hours velocity of wind.	Wind in Central Japan at			Remarks.
Feb.					Killo.	6 a.m.	2 p.m.	9 p.m.	
19	Trems. from 10 a. to	Trems. strong at 11 and 12 p. They extend from 4 p. to	After 4 a.	57.6	513.2	0	W	W	
20	Noon.	10 or 11 a.	... ...	59.9	596.5	WT2	W	0	
21	... ...	... ...	... ...	64.5	632.9	0	WT3	WT3	
22	... ...	... ...	... ...	68.9	282.9	0	0	0	
23	... ...	... ...	... ...	70.5	312.7	0	0	0	
24	... ...	... ...	... ...	70.8	276.1	0	0	0	
25	Trems. from 7 a. to 10 a.	Trems. from 9.45 a. to 7 p.	... ...	61.1	292.7	WT2	W	W	
26	... ...	... ...	... ...	63.4	318.3	0?	W?	WT3	
27	... ...	Two slight waves at 9.30 p.	1.37.29 p. 2° 0′	61.6	276.9	0	0	0	
28	Trems. from 6 to midnight.	Slight waves at 4.30 a., 5.30 p., and from 7.30 p. many waves.	10.20.05 p. 2° 50′	56.2	256.8	0	W	0	At 2 p. wind in Tokio=1.
Mar. 1	Slight trems. 11 a. to midnight.	Slight trems. 4 p. to	... ...	59.9	324.7	0	W	0	At 9 p. the center of Bar. depression is
2	Trems. from noon to 11 p.	1 a.	... ...	63.5	326.8	0	0	0	[in Yezo.

3	... ...	Trems. from midnight, 2 to 4 a. trems. are 2m.-3m. & at 7 a. 3m to 4m.	... ...	59.4	481.4	0	W	0	
4	... ...	4.30 a., slight deflection.	... ...	67.0	578.0	WT_3	W	WT_3	
5	... ...	Slight trems. at 8 p.	... ...	68.6	266.6	0	0	0	
6	Trems. from 4 p. to	10.30 a. Slight deflection. Slight trems. 3 p. to 10 p. At 4 p. they are 4m.	... ...	58.3	318.4	0	0	WT_3	
7	1 a.	Slight trems. and slight deflections. at 12.30 p.	... ...	62.5	361.1	0	0	0	
8	Trems. 3 p. to 8 p. Maximum at 5 p.	Slight trems. 6-7 a. At 2 p. they are 2m. Continue to 8 p.	After 7 p. 1° 00′	58.8	421.3	0	W	WT_3	
9	... ...	8 a. two slight waves $\frac{1}{10}$	... ...	59.3	258.3	0	W	0	
10	... ...	... ...	... ...	60.4	508.1	0	W	0	At 2 p. wind in Tokio=0.
11	... ...	... ...	... ...	60.8	207.7	0	0	0	At 9 p. low Bar. to East.
12	... ...	Slight trems. 9 to 10 a.	At 1.0.0 p. and 4.8.13 p. 4° 20′	65.2	549.2	W	W	0	At 6 a. wind in Tokio=0.
13	... ...	... ...	... ...	69.6	430.9	0	W	0	
14	... ...	... ...	... ...	72.2	284.4	0	0	0	
15	... ...	... ...	... ...	71.2	257.1	0	0	0	

	North-South. Component.	East-West Component.	Earthquakes.	Barometer reduced 0° C. at sea level +700.	24 hours velocity of wind.	Wind in Central Japan at			Remarks.
Mar.					Killo.	6 a.m.	2 p.m.	9 p.m.	
16	Trems. from 4 p. (at 10 p. 3m. to 4m.) to	Trems. from 4 p. (from 9 a. to 1 p. they are 4m.) continue to	... ...	57·4	437·3	0	W	W	At 2 p. in Tokio wind =2 and Bar. 758—at 9 p. wind=4 Bar. 745.
17	1 p. Again from 2 p. to 10 p.	6 p.	... ...	55·9	753·4	W	W	W	At 6 a. in Tokio wind =3 and Bar. 751—at 2 p. wind=4 Bar. 757. Between 2 p. on the 16th to 6 a. on the 17th the center of depression travelled over Tokio from Kobe to Sendai.
18	... ...	... ...	... ...	63·3	497·4	WT3	W	WT3	
19	... ...	... ...	... ...	67·5	418·9	0	0	0	
20	... ...	... ...	At 1.1.13 p. and 2.21.40 p. 22° 0′	62.0	389.8	0	W	0	
21	Trems. 1 p. to	Trems. 1 a. to 2 p. at 1 p. they are 2m.	... ...	48.8	736.1	W?	W	W	At 9 p. wind in Tokio=0.
22	3 a. From 3 a. to 6 a. feeble.	Trems. 9 a. to 1 p. They are 1m.	... ...	54·5	348.3	W	W	0	At 6 a. and 2 p. wind in Tokio=2
23	... ...	... ...	2.31.28 a.	57.0	311.8	0	WT3	0	[and 1.
24	... ...	... ...	After 2 a.	62.3	205.5	0	0	0	
25	... ...	... ...	... ...	62.4	238.4	0	W	0	
26	... ...	... ...	... ...	62.7	144.0	0	0	0	

See Maps.

27	3 p. to 7 p. irregularities. Trems. 10 p. to	Slight trems. 11 p. to	2.27.35 p.	1° 30′	52.6	288.8	o	W	o	At 2 p. wind in Tokio=2.
28	7 a.	3 a. Again slight trems. 7 to 10 a.	About 1.7.0 a.		59.1	652.3	W	WT_4	WT_3	At 6 a. wind in Tokio=1.
29	... ...	... ...	... ...		62.5	155.8	o	o	o	
30	Slight trems. 5 a. to 9 a.	Slight trems. 5 to 7 a.	... ...		60.5	298.3	o	W	o	At 6 a. Bar. low to 9 and at 2 p. low over Tokio.
31	... ...	... ...	... ...		67.3	220.5	o	o	o	
April 1	Trems. from 5 p. to	Trems. from 3 p. to	... ...		66.6	332.5	o	o	W	
2	10 a.	3 a.	... ...		63.4	466.8	W	W	o	At 6 a. Bar. low near Tokio.
3	... ...	... ...	... ...		70.0	222.1	o	o	o	
4	... ...	... ...	... ...		61.7	148.2	o	o	o	
5	... ...	Slight trems. 10 to 12 a.	... ...		69.9	341.8	o	o	o	
6	... ...	... ...	... ...		59.9	388.8	o	WT	o	
7	... ...	... ...	After 2 a.		69.1	184.5	o	o	o	
8	... ...	... ...	... ...		60.6	628.6	o	WT_4	W	
9	... ...	... ...	... ...		59.2	534.7	W	o	o	
10	... ...	... ...	... ...		66.7	302.6	o	o	o	
11	... ...	... ...	... ...		63.6	257.1	o	WT_3	o	
12	Trems. 7 p. to midnight.	Trems. 7 p. to 11 p. At 9 p. strong.	... ...		64.1	393.7	o	W	WT_3	
13	... ...	... ...	... ...		65.6	172.9	o	o	o	
14	Trems. 9 a. to	Slight trems. 11 a.	... ...		55.0	504.0	WT_4	W	W	
15	3 a.	... ...	... ...		64.1	370.8	o	o	o	
16	... ...	... ...	... ...		65.9	391.0	o	o	WT_3	

April	North-South Components.	East-South Component.	Earthquakes.	Barometer reduced 0° C. at sea level +700.	24 hours velocity of wind.	Wind in Central Japan at			Remarks.
					Killo.	6 a.m.	2 p.m.	9 p.m.	
17	Trems. 11 p. to	Trems. 11 a. to midnight.	... ...	61.7	347.0	0	0	0	At 9 p. Bar. low near Tokio.
18	3 a.	... ...	... ...	67.0	191.3	0	0	0	
19	... ...	... ...	... ...	69.4	258.7	0	0	0	
20	Trems. 3 a. to 6 a. then quiet.	... ...	... ...	62.0	288.9	0	0	0	
21	... ...	... ...	... ...	54.4	240.4	0	W	0	
22	... ...	... ...	... ...	63.1	253.3	0	W	0	
23	Trems. 11 a. very slight.	... ...	11.52.24 a.	72.4	382.6	0	W	0	
24	... ...	... ...	7.1.53 p.	70.8	266.1	0	0	0	
25	... ...	... ...	After 1 p.	66.9	329.9	0	WT3	0	
26	... ...	... ...	... ...	64.5	397.8	0	WT4	0	
27	Trems. 5 a. (maximum at 7 a.) to 8 p.	Trems. 6 a. till 3 p. Range 1.5m.	... ...	53.3	464.0	WT4	W	W	
28	... ...	... ...	... ...	61.3	426.8	0	W	W	
29	... ...	... ...	... ...	55.6	593.3	0	0	0	
30	Trems. 7 a. to 2 p. Again 4 p. to 9 p.	Trems. 7 a. to 2 p. They continue till midnight. At 7 to 8 p. a maximum.	... ...	57.4	503.7	W	W	0	At 6 a. Bar. low near Tokio.

May									
1	... ...	... ...	2.47.27 a.	62.1	257.1	o	W	o	
2	... ...	... ...	... ...	66.3	322.8	o	W	o	
3	... ...	... ...	... ...	68.8	401.7	o	W	o	
4	... ...	... ...	... ...	66.1	524.3	o	W	WT_3	
5	... ...	8 or 9 p. trems. until	... ...	57.5	747.8	o	WT_3	W	
6	Trems. 1 a. to 10 a.	4 a.	... ...	54.6	334.8	o	W	o	
7	... ...	... ...	8.58.08 a.	60.2	358.9	o	W	WT	
8	... ...	... ...	... ...	65.9	427.5	o	W	WT	
9	... ...	... ...	... ...	60.9	174.4	o	o	o	
10	... ...	... ...	... ...	55.5	259 2	o	o	o	
11	Slight trems. 11 a. to 3 p.	... ...	... ...	49.1	277.5	o	W	W	
12	... ...	... ...	... ...	57.4	458.4	o	W	o	
13	... ...	... ...	... ...	57.1	242.4	o	WT	o	
14	Trems. 7 p. until 10 p. Well defined.	Trems. 7 p. to 10 p. At 9 p. 2m.	... ...	60.6	381.2	o	W	o	
15	... ...	... ...	... ...	64.9	283.6	o	o	o	
16	Trems. 2 a. to 12 noon.	Slight trems. at 6 a.	... ...	65.8	365.7	o	W	W	
17	Trems. 9.30 a. to 6 p.	Slight trems. 11 a. to 3 p.	... ...	64.1	383.1	W	o	W	
18	Trems. 6 a. to 9 p. of 2m.	Trems. 6 p.	... ...	57.4	410.0	W	W	o	Bar. low near Tokio.
19	... ...	... ...	About 2.50 a.	51.6	308.7	o	W	o	
20	... ...	... ...	... ...	51.9	288.0	o	W	o	
21	... ...	... ...	... ...	54.9	338.6	o	WT	o	
22	... ...	... ...	... ...	60.3	270.7	o	o	o	
23	... ...	... ...	... ...	62.5	411.6	o	WT_3	WT_3	
24	... ...	... ...	... ...	59.2	409.2	o	WT_3	o	

	North-South Component.	East-West Component.	Earthquakes.	Barometer reduced 0° C. at sea level +700.	24 hours velocity of wind.	Wind in Central Japan at			Remarks.
May					Killo.	6 a.m.	2 p.m.	9 p.m.	
25	... ...	... ...	... ...	59.6	221.5	o	o	o	
26	... ...	Slight trems. 8.30 a.	... ...	60.3	286.0	o	o	o	
27	... ...	... ...	... ...	57.3	331.7	o	o	o	
28	Slight trems. 9.30 a. to 3 p.	... ...	... ...	55.1	237.1	o	o	o	Bar. low near Tokio.
29	... ...	... ...	... ...	63.1	389.5	o	o	o	
30	... ...	... ...	... ...	67.8	451.5	o	WT3	WT3	
31	... ...	Slight trems.	... ...	64.7	774.5	WT3	W	W	
June									
1	Trems. 10.45 a. to 8 p.	Slight trems. till 2 p.	... ...	58.2	646.9	WT4	W	o	
2	... ...	... ...	... ...	59.4	222.8	o	o	o	
3	... ...	... ...	... ...	58.3	150.7	o	o	W	
4	... ...	... ...	... ...	55.9	621.2	W	W	o	
5	... ...	... ...	... ...	62.5	235.7	o	o	o	
6	... ...	... ...	... ...	64.6	126.3	o	o	o	
7	... ...	... ...	11.34.18 p.	64.5	213.1	o	WT3	o	
8	... ...	... ...	... ...	63.6	133.5	o	o	o	
9	... ...	... ...	... ...	58.4	234.0	o	o	o	
10	... ...	... ...	... ...	55.7	180.4	o	o	o	[Tokio.
11	... ...	... ...	9.19.40 a. $\frac{1.6}{2.2}$	57.0	506.6	o	o	o	At 6 a. Bar. low at
12	... ...	... ...	... ...	60.8	208.2	o	o	o	

June 13	... ...	... ...	... ...	57.4	229.2	0	WT_3	0	[Tokio.
14	... ...	... ...	... ...	56.2	256.1	0	WT_3	0	At 9 p. Bar. low near
15	... ...	... ...	1.41.41 a. $\frac{5.9}{2.3}$ 8.40.0 a.	54.7	289.5	0	0	0	
16	... ...	... ...	... ...	53.6	192.8	W	0	0	
17	... ...	... ...	... ...	54.8	162.3	0	0	0	Bar. low near Tokio.
18	... ...	... ...	1.36.45 p. $\frac{.8}{1.8}$	58.5	265.5	0	0	0	
19	... ...	4.45 a. slight wave.	... ...	61.0	232.7	0	0	0	
20	Trems. 6 a. to 8 a. Slightly wavy.	... ...	... ...	59.4	288.9	0	0	0	
21	... ...	... ...	... ...	54.3	435.2	WT_3	W	0	[Tokio. At 2 p. Bar. low near
22	... ...	... ...	... ...	53.3	250.4	0	0	0	
23	... ...	... ...	... ...	54.9	216.8	WT_3	0	0	
24	... ...	... ...	... ...	56.1	227.8	0	0	0	
25	... ...	... ...	... ...	57.8	271.2	0	0	WT_3	
26	... ...	... ...	... ...	55.5	296.4	0	0	0	
27	... ...	... ...	... ...	55.0	355.8	0	W	0	
28	... ...	... ...	2.24.18 a.	56.4	152.3	0	0	0	
29	... ...	... ...	... ...	58.4	218.2	0	0	0	
30	Trems. 10 p.?	... ...	11.45 p. small.	59.3	214.9	0	0	0	
July 1	Trems. 12 noon to 3 p.	Slight trems. 10 a. to 4 p.	... ...	54.1	660.7	0	W	W	At 2 p. and 9 p. Bar. low at Kobe.
2	Trems. 10 a. to 4 p. Slight waves.	Slight trems. 10.15 a. to 8 p.	... ...	47.2	681.9	W	W	0	At 6 a. Bar. low at Niigata—at 2 p. low at Sendai.
3	... ...	... ...	8 p. small.	54.9	154.1	0	0	0	
4	... ...	... ...	... ...	55.3	221.2	0	0	0	
5	... ...	... ...	... ...	54.7	266.5	0	0	0	
6	... ...	... ...	... ...	54.4	245.8	0	0	0	

	North-South Component.	East-West Component.	Earthquakes.	Barometer reduced 0° C. at sea level +700.	24 hours velocity of wind.	Wind in Central Japan at			Remarks.
July					Killo.	6 a.m.	2 p.m.	9 p.m.	
7	... ...	... ...	... ...	57.2	240.8	0	0	0	
8	... ...	... ...	... ...	59.2	201.6	0	0	0	
9	... ...	... ...	... ...	58.5	325.3	0	WT3	WT3	
10	... ...	... ...	... ...	56.9	195.4	0	0	W	
11	... ...	... ...	... ...	57.3	156.5	0	W	0	
12	... ...	... ...	... ...	60.4	207.6	0	0	0	
13	... ...	... ...	... ...	61.3	262.4	0	WT3	0	
14	... ...	... ...	... ...	61.1	178.0	0	0	0	
15	... ...	... ...	... ...	58.0	336.2	0	0	0	
16	... ...	... ...	... ...	55.9	207.6	0	0	0	
17	... ...	... ...	... ...	53.4	204.1	0	W	0	
18	Trems. 7 p. to midnight.	Trems. 7 p. to 1 a.	... ...	55.6	378.9	0	W	0	All day Bar. low over Tokio.
19	... ...	... ...	... ...	56.6	238.5	0	W	W	
20	... ...	... ...	... ...	58.8	500.8	0	WT3	WT3	
21	... ...	... ...	... ...	60.9	433.0	0	WT4	WT3	
22	... ...	... ...	... ...	62.7	325.2	0	WT3	0	
23	... ...	... ...	... ...	60.2	372.1	0	0	0	At 2 and 9 p. low in Central Japan.
24	... ...	... ...	... ...	62.3	510.9	0	WT3	WT3	
25	... ...	... ...	... ...	62.2	390.3	0	WT3	0	
26	... ...	... ...	... ...	59.9	617.9	0	WT4	WT3	

27	... ...	... ...	... ...	10.2	429.8	0	WT_3	0	
28	... ...	... ...	... ...	62.6	154.7	0	0	0	
29	... ...	... ...	... ...	63.7	212.3	0	0	0	
30	... ...	... ...	... ...	63.3	302.3	0	WT_3	0	
31	... ...	Trems. 1 p. to 1 a. on August 1st, a maximum at 8 p.	... ...	61.5	409.1	0	WT_3	WT_3	
Aug.									
1	... ...	... ...	... ...	61.1	501.1	0	WT_3	WT_3	
2	... ...	... ...	... ...	62.3	348.9	0	WT_3	0	
3	... ...	... ...	... ...	62.5	290.3	0	0	0	
4	... ...	... ...	... ...	59.1	441.0	0	WT_3	0	
5	... ...	... ...	... ...	57.5	501.0	WT_3	WT_3	0	
6	... ...	... ...	... ...	58.0	653.8	WT_4	WT_3	WT_3	
7	... ...	Slight trems. 4 p.	... ...	59.3	732.1	WT_3	WT_3	0	
8	... ...	... ...	... ...	61.2	631.9	0	WT_4	0	
9	... ...	... ...	2.30 p.	63.5	293.1	0	0	0	
10	... ...	... ...	... ...	64.5	231.4	0	0	0	
11	... ...	... ...	... ...	63.7	221.8	0	0	0	
12	... ...	... ...	... ...	61.2	273.0	0	0	0	
13	... ...	... ...	... ...	58.2	210.8	0	0	—	No map for 9 p.
14	... ...	... ...	... ...	58.6	283.3	0	0	0	
15	... ...	... ...	... ...	59.6	205.3	0	WT_3	0	
16	... ...	... ...	... ...	58.2	296.5	0	WT_3	0	
17	... ...	... ...	... ...	55.9	360.5	0	WT_3	0	
18	... ...	Slight trems. 11 p. to	... ...	54.3	305.9	0	WT_3	WT_3	At 9 p. low near Tokio.
19	... ...	4 a.	... ...	57.9	338.3	0	0	0	
20	... ...	... ...	4 a.	60.2	169.4	0	0	0	
21	... ...	Slightly wavy	... ...	60.5	186.4	0	0	0	

	North-South Component.	East-West Component.	Earthquakes.	Barometer reduced 0° C. at sea level +700.	24 hours velocity of wind.	Wind in Central Japan at			Remarks.
						6 a.m.	2 p.m.	9 p.m.	
Aug.					Kilo.				
22	... ...	... ...	... ...	61.7	197.5	0	0	0	
23	... ...	... ...	... ...	61.7	242.4	0	0	0	
24	... ...	4.15 a. slight deflection.	... ...	58.6	314.7	0	WT3	0	
25	... ...	... ...	... ...	57.6	207.6	0	0	0	
26	... ...	... ...	5.02.30 a.	60.2	157.2	0	0	0	
27	... ...	... ...	... ...	56.0	234.5	0	W	0	
28	... ...	... ...	9.37.28 a.	56.9	361.4	0	WT3	0	
29	... ...	... ...	... ...	54.8	297.4	0	WT3	0	
30	... ...	... ...	... ...	55.1	341.1	0	WT3	0	
31	7 p. to 11 p. Trems.	Trems. 7 p. to 10 p. A maximum at 7.15 p. These trems. are like a continuous earthquake, 4m. range.	5.23.55 a.	56.6	443.5	0	WT4	0	At 2 p. low in Central Japan.
Sept.									
1	... ...	... ...	... ...	61.4	208.2	0	0	0	
2	... ...	... ...	8.31.42 a. $\frac{\cdot 4}{\cdot 4}$	62.3	234.6	0	0	0	
3	... ...	... ...	... ...	62.0	275.2	0	0	0	
4	... ...	... ...	... ...	5.95	173.7	0	0	0	

5	Slight trems. 6 a. Also 6 p. to	... ...	7.30 p.		58.6	327.4	o	WT_3	WT_3	At 2 p. and 9 p. a strong wind to the
6	2 a.	... ...	... ...		62.7	253.9	o	W	o	South.
7	... ...	... ...	... ...		60.3	216.2	o	WT_3	o	
8	... ...	... ...	... ...		59.6	252.8	o	o	o	
9	... ...	... ...	... ...		60.7	201.4	o	o	o	
10	... ...	... ...	8.19.06 p.		62.8	229.3	o	o	o	
11	... ...	... ...	1.24.30 a.		64.4	210.0	o	o	o	
12	... ...	... ...	... ...		63.7	208.4	o	o	o	
13	... ...	... ...	... ...		62.8	336.9	o	WT_3	o	
14	... ...	... ...	... ...		61.4	536.1	o	WT_3	WT_3	
15	... ...	... ...	... ...		58.8	506.0	o	WT_3	WT_3	
16	... ...	... ...	... ...		59.4	286.5	o	o	o	
17	... ...	... ...	... ...		58.8	219.4	o	o	o	
18	Slight trems. 11.30 a. to 1 p.	... ...	... ...		51.2	597.1	o	W	WT_3	At 6 a. and 2 p. low in Central Japan.
19	... ...	... ...	... ...		52.2	668.8	WT_3	W	W	
20	... ...	... ...	1.13.50 a.	.4 / .4	59.7	286.5	o	o	o	
21	... ...	... ...	... ...		63.2	216.1	o	o	o	
22	... ...	... ...	2.29.43 a.	.8 / 1.6	62.0	203.6	o	o	o	
23	... ...	... ...	... ...		55.5	135.6	o	o	o	
24	Slight trems. 7 p. to 12 p.	... ...	11 p.		56.3	243.8	o	o	o	
25	Trems. 11 p.	... ...	... ...		57.8	324.2	o	WT_3	o	
26	Trems. 11 a. to 1 p.	... ...	0.2.45 p.	13.7 / .3	57.4	193.4	o	o	o	
27	Slight trems. 8 a. to 10 a.	... ...	... ...		58.9	134.6	o	o	o	
28	Slight trems. 5.30 a. to 8.30 a.	... ...	5.15 a. and 5.27.43 a.	11.1 / 2.2	63.3	171.6	o	o	o	

	North-South Component.	East-West Component.	Earthquakes.	Barometer reduced 0° C. at sea level +700.	24 hours velocity of wind.	Wind in Central Japan at			Remarks.
						6 a.m.	2 p.m.	9 p.m.	
Sept.					Kilo.				
29	Large trems. 1 a.	... ...	8.39.9 a.	64.5	220.7	0	0	0	
30	... ...	... ...	... ...	62.9	208.7	0	W	0	
Oct.									
1	Trems. 12 noon to	Slight trems. 11 a. to 4 p.	1.8.57 p. $\frac{\cdot 8}{\cdot 5}$	66.6	279.4	0	0	0	
2	12 noon.	... ...	7.30 a.	64.4	453.3	0	W	0	
3	... ...	... ...	... ...	66.1	200.7	0	0	0	
4	... ...	... ...	... ...	67.0	250.1	0	0	0	
5	Slight tremors.	... ...	10 a.	66.3	321.4	0	0	0	
6	... ...	Slight tremors 8 p.	... ...	63.9	350.2	WT3	0	0	
7	Wavy.	... ...	7.34.45 a.	59.7	352.8	0	0	0	[Japan.
8	... ...	... ...	... ...	57.0	208.6	0	0	0	Low Bar. in Central
9	... ...	... ...	7.53.5 p.	55.3	159.7	0	0	0	
10	... ...	... ...	... ...	59.5	268 9	0	0	0	
11	... ...	... ...	5.30 a. about	66.9	243.9	0	0	0	
12	... ...	... ...	... ...	69.3	294.4	0	0	0	
13	Tremors or earthquake 4 p.	... ...	4 p. ?	67.4	280.2	0	0	0	
14	... ...	... ...	... ...	58.3	225.8	0	0	0	Bar. low near Tokio.
15	... ...	Irregular line.	9.2.29 a. and 8.43.18 p. $\frac{\cdot 3}{1.1}$	59.0	140.8	0	0	0	

16	Trems. from 5 a. to 10 p. At 11 and 12 o'clock, 4m.	Trems. from 5 a. to 10 p. At 11 and 12 o'clock, 4m.	... ...		56.1	662.0	WT3	o	o	At 6 a. wind generally strong. Bar. low.
17	... ...	... ...	... ...		64.8	148.9	o	o	o	
18	... ...	... ...	... ...		66.7	276.2	o	o	o	
19	... ...	... ...	... ...		69.9	248.5	o	o	o	
20	... ...	... ...	... ...		62.4	310.1	o	o	o	
21	... ...	... ...	1.19.35 a.	.2/.9	59.1	299.4	o	o	WT3	
22	... ...	... ...	... ...		62.2	311.3	o	o	o	
23	... ...	... ...	... ...		64.5	218.6	o	o	o	
24	Slight trems. 7 a. to 3 p.	Trems. noon to 2 p. of 2m.	5.12.58 a.	.2/.9	58.3	315.8	o	o	o	Bar. low over Tokio.
25	... ...	Slight trems. at 3 p.	... ...		57.0	117.4	o	o	o	
26	... ...	... ...	10.41.11 p.	1.9/2.9	58.7	285.2	o	o	W	
27	... ...	Slight trems. 8 a.	... ...		61.7	259.8	o	o	o	
28	... ...	... ...	... ...		63.4	256.5	o	o	o	
29	Trems. 6 a. to 9 a.	... ...	... ...		66.8	307.6	WT3	o	o	
30	... ...	... ...	8.31.16 p.	.2/1.5	68.7	261.2	o	o	o	
31	... ...	... ...	... ...		66.7	205.2	o	o	o	
Nov.										
1	... ...	... ...	... ...		66.1	230.8	o	o	o	
2	... ...	... ...	... ...		63.7	282.7	o	o	o	flow near Tokio.
3	... ...	... ...	... ...		58.8	320.3	WT3	o	o	At 6 a. and 2 p. Bar.
4	... ...	... ...	... ...		58.6	291.4	o	WT3	WT3	
5	Trems. 7 a. to 5 p. From 11 a. to 1 p., 2m.	Trems. 7 a. to 9 p. From 11.30 to 2 p., 2.5m.	... ...		54.4	591.5	W	W	W	At 6 a. low in Cen-Japan; at 2 p. low in N. Yezo; at 9 p. wind in Tokio=o.
6	... ...	... ...	... ...		68.7	182.1	WT3	o	o	
7	... ...	... ...	11 p. small.		72.4	240.3	o	o	o	

	North-South Component.	East-West Component.	Earthquakes.	Barometer reduced 0° C. at sea level +700.	24 hours velocity of wind.	Wind in Central Japan at			Remarks.
						6 a.m.	2 p.m.	9 p.m.	
Nov.					Kilo.				
8	... ...	... ...	... ...	68.8	181.5	0	0	0	
9	... ...	... ...	... ...	63.4	356.4	0	0	0	[of Tokio.
10	... ...	... ...	... ...	55.9	270.5	0	0	0	At 6 a. low to East
11	... ...	Slight trems. 1 p. to 5 p.	8.51.24 p.	58.4	233.4	0	0	0	
12	Noon to 7 p. strong, continue to 10 p.	Trems. 11 a. to 10 p. strong at 5 p.	... ...	57.9	380.9	W	W	0	
13	... ...	... ...	... ...	68.2	247.4	0	W	0	
14	... ...	... ...	... ...	71.8	226.8	0	0	0	
15	... ...	... ...	... ...	70.8	196.2	0	0	0	
16	... ...	... ...	1.50.36 p. $\frac{2}{7}$	74.8	172.0	0	0	0	
17	... ...	... ...	... ...	70.5	205.3	0	0	0	
18	... ...	... ...	... ...	59.0	200.7	0	0	0	
19	Trems. midnight to	Trems. 9 a. to 3 p.	... ...	59.7	218.2	0	W	0	
20	5 p.	Slight trems. 8 a. to 3 p.	7.41.35 p.	62.9	189.2	0	0	0	Bar. low to East.
21	Trems. 9 a. to 10 a.	... ...	... ...	62.0	288.3	0	0	W	
22	Trems. 5 p. large again at 11 p. to midnight and on to	... ...	... ...	68.3	466.9	0	WT3	0	
23	4 a.	Noon to	... ...	66.6	406.3	0	0	WT3	

24	... ...	5 a.	... ...	51.8	199.2	o	o	W	
25	Trems. slight noon to 4 p.	Slight trems. 10 a. to 6 p.	... ...	47.4	441.3	W	W	W	At 2 p. and 9 p. wind at Tokio=2 and Bar. low in N. Nippon.
26	... ...	... ...	... ...	55.5	167.9	o	W	o	
27	... ...	... ...	... ...	63.0	200.8	o	o	o	
28	... ...	Slight trems. from 3.45 a. to 9 a.	3 a. and at 8 a.	54.3	374.1	o	W	W	At 2 and 9 p. low in north.
29	... ...	... ...	... ...	55.0	420.5	W	W	W	Bar. low in north.
30	... ...	... ...	... ...	61.4	253.1	o	o	o	

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	North-South Component.	East-West Component.	Earthquakes.	Barometer reduced 0° C. at sea level +700.	24 hours velocity of wind.	Remarks.	Wind Intensity Barometer Gradient.		
Jan.					Kilo.		6 a.m.	2 p.m.	9 p.m.
20	... ...	* 6 a. to 10 p. trems. 1mm.	... ...	65.4	230.1	... ...	$\frac{1}{4}$	$\frac{2}{0}$	$\frac{0}{5}$
21	Slight trems. at 10 p.	* 3 a. to midnight slight trems.	... ...	52.7	338.7	Not working in morning.	$\frac{1}{1}$	$\frac{3}{5}$	$\frac{1}{5}$
22	Slight trems. 10 a.	* From midnight to 6 a. slight trems.	10.58.0 p.	58.3	414.3	Fine, calm; not working.	$\frac{1}{5}$	$\frac{3}{5}$	$\frac{2}{2}$
23	... ...	Slight trems. 10 a.	... ...	58.4	231.7	Fine, calm.	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{3}$
24	... ...	4 a. to 3 p. slight.	... ...	60.1	377.3	Fine.	$\frac{2}{2}$	$\frac{2}{3}$	$\frac{2}{2}$

	North-South Component.	East-West Component.	Earthquakes.	Barometer reduced 0° C. at sea level +700.	24 hours velocity of wind.	Remarks.	Wind Intensity Barometer Gradient.		
							6 a.m.	2 p.m.	9 p.m.
Jan.					Kilo.				
25	... ...	... ...	... ...	62.6	241.3	Fine.	2/2	2/1	1/2
26	} Not working.			59.7	234.9	Fine.	...	...	...
27		... ...	... ...	61.0	229.3	Fine.	...	...	...
28				62.0	159.3	Fine.	...	...	...
29	Slight trems.	Slight trems.	... ...	63.7	263.9	... ...	2/5	2/2	2/1
30	Not working.	Not working (slight trems.?)	... ...	57.0	432.8	Snow.	...	...	...
31	Slight trems. all day.	Slight trems.	7.22.46 a.	48.2	236.5	Snow stopped but lies thick on the ground.	2/2	2/2	1/2
Feb.									
1	Slight trems.	Slight trems.	Slight quake 7 a.	48.6	145.6	Snow on ground, thawing, fine.	2/1	1/1	1/2
2	Slight trems. 8-10 p.	Very slight trems.	... ...	53.1	304.9	Fine, frosty, trems. appear strong.	2/5	3/5	3/5
3	... ...	* Very slight trems.	... ...	57.2	231.7	Fine, trems. moderate.	2/2	2/2	1/3
4	... ...	... ...	... ...	63.3	389.4	Fine, trems. moderate.	1/3	4/3	2/5
5	... ...	... ...	... ...	68.7	154.5	Fine.	1/3	2/2	1/1
6	Trems. from midnight to	6 a. trems. 2m.	... ...	63.5	326.6	Fine.	0/2	3/2	0/3

7	Midnight.	4 a. strong trems. at 11 p. 3m. continuing all day.	... ...	50.6	236.5	Fine, rain and wind at night, rapid thaw.	0/4	2/6	1/9
8	Slight trems. 9 p.	... ...	... ...	55.4	323.4	Fine, rain and wind.	3/4	1/5	2/3
9	Slight trems. 4 p.		... ...	56.3	222.8	Fine, trems. very slight. Frost.	1/2	1/4	1/2
10	... ...		... ...	58.8	146.4	Fine.	0/2	2/3	0/3
11	Slight trems.		... ...	58.6	237.3	Fine, cold.	2/3	2/3	0/3
12	Slight trems.	Very slight trems.	... ...	57.8	354.8	Fine, cold.	3/5	3/4	1/4
13	... ...		Slight quake 4 p.	59.2	164.9	Fine, cold, slight trems.	2/5	2/4	1/3
14	... ...		... ...	61.0	230.1	Fine, cold, no trems.	1/4	2/4	2/4
15	... ...		... ...	65.4	373.3	Fine, cold.	1/2	2/2	1/2
16	... ...	* Slight trems.	... ...	61.9	171.4	Light snow, no wind.	3/3	1/2	1/2
17	Slight trems. 12-4 p.	... ...	... ...	61.7	403.9	Fine. At 3.30 a. slight quake.	2/3	4/3	2/3
18	... ...	... ...	... ...	67.3	270.3	Fine.	2/3	2/2	1/1
19	... ...	... ...	2.54.11 a.	68.0	275.9	Fine.	1/0	1/1	2/1
20	... ...	... ...	... ...	70.0	405.5	Fine.	3/2	3/2	0/0
21	Not working.	Not working.	... ...	69.6	121.5	Fine, cold.	...	...	...
22	Slight trems.	Slight trems. 2 a. 2mm.	... ...	58.4	196.3	Fine.	1/1	1/4	1/4
23	Slight trems. 3 p.	Slight trems.	... ...	61.3	270.3	Fine.	2/3	2/5	2/4
24	... ...	* Slight trems. until 2 p.	7.34.0 a. and 3.36.25 p. .5/.6 .02	67.1	304.1	Fine.	2/1	2/0	0/2
25	Slight trems. ?	... ...	... ...	68.7	186.6	Fine.	2/2	0/1	0/1
26	... ...	Moderably strong trems. at 3 a.	... ...	61.1	198.7	Fine.	1/1	2/4	2/5
27	... ...	* 2 a. trems. 2mm. and slight all day.	... ...	62.2	303.3	Fine.	2/3	1/0	0/3

	North-South Component.	East-West Component.	Earthquakes.	Barometer reduced 0° C. at sea level +700.	24 hours velocity of wind.	Remarks.	Wind Intensity Barometer Gradient.		
							6 a.m.	2 p.m.	9 p.m.
Feb. 28	... ...	* Very slight.	... ...	63.7	Kilo. 366.0	Fine.	$\frac{2}{2}$	$\frac{3}{2}$	$\frac{2}{3}$
Mar. 1	... ...	... ...	... ...	67.2	314.6	Fine.	$\frac{2}{2}$	$\frac{3}{2}$	$\frac{1}{2}$
2	... ...	Exceedingly small trems 9 p.	2.03.49 a. $\frac{\cdot 4}{1.4}$	69.6	330.6	Fine, trems. moderately strong although no wind.	$\frac{2}{1}$ $\frac{1}{2}$	$\frac{3}{2}$ $\frac{2}{2}$	$\frac{2}{2}$
3	... ...	... ...	... ...	68.9	418.3	Snow.	$\frac{1}{5}$	$\frac{3}{5}$	$\frac{3}{3}$
4		... ...	... ...	68.1	370.9	Snow.	$\frac{2}{3}$	$\frac{2}{2}$	$\frac{2}{2}$
5		... ...	... ...	68.6	239.7	Snow.	...	...	...
6		Slight trems.	... ...	69.5	339.5	Snow.	$\frac{2}{2}$	$\frac{2}{3}$	$\frac{1}{3}$
7		... ...	... ...	73.3	223.7	Snow.	...	...	...
8		... ...	... ...	71.7	160.9	Snow.	...	...	...
9	Not working well.	... ...	... ...	58.9	246.2	Snow.	...	...	...
10		... ...	... ...	60.5	515.7	Snow.	...	...	...
11		... ...	... ...	64.5	501.2	Snow.	...	...	...
12		... ...	... ...	68.0	339.5	Snow.	$\frac{1}{3}$	$\frac{2}{2}$	$\frac{1}{3}$
13		... ...	6.25.0 p. $\frac{\cdot 3}{1.4}$	59.7	275.9	Snow.	...	...	...
14		... ...	... ...	59.3	514.1	Snow.	...	...	...
15		... ...	... ...	69.8	281.6	Snow.	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{1}{2}$
16	Slight trems.	Slight trems.	... ...	72.5	216.4	Snow.	$\frac{1}{3}$	$\frac{1}{1}$	$\frac{0}{2}$
17	... ...	* Slight trems.	... ...	71.1	276.7	Snow.	$\frac{1}{2}$	$\frac{3}{2}$	$\frac{2}{3}$

18	Large trems. max. 3 p.-8 p. on the 20th 2m.	* Slight trems.	... ...	65.9	635.6	Snow.	$\frac{2}{3}$	$\frac{3}{2}$	$\frac{3}{4}$
19		Large trems. at 3 p. 4m. max. at 9 p.	... ...	55.5	844.1	Heavy gale. Trems. and wind.	$\frac{4}{4}$	$\frac{4}{7}$	$\frac{4}{7}$
20			... ...	62.6	526.9	Heavy gale.	$\frac{3}{5}$	$\frac{2}{5}$	$\frac{2}{2}$
21	... ...	* Slight at 9 a.	... ...	60.6	183.4	Fine, cold.	$\frac{1}{3}$	$\frac{1}{1}$	$\frac{0}{0}$
22	Slight trems.	Slight trems.	... ...	59.6	266.3	Fine.	$\frac{2}{1}$	$\frac{1}{2}$	$\frac{1}{1}$
23	Continuous trems.	Trems.	... ...	60.5	278.9	Fine.	$\frac{2}{1}$	$\frac{2}{2}$	$\frac{3}{3}$
24	Large trems. 10-12 p. of 4mm.	Large trems. max. at 12 p.	... ...	53.8	680.7	Heavy wind tremors and swing 2-4mm.	$\frac{1}{2}$	$\frac{4}{7}$	$\frac{2}{6}$
25	Slight trems. all day.	Trems.	... ...	61.5	273.5	Rain and no wind.	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{1}$
26	... ...	* Slight trems.	6.6.0 a.	60.5	135.2	Fine.	$\frac{0}{2}$	$\frac{1}{3}$	$\frac{1}{2}$
27	Slight trems. 2 a.-8 p. max. at 8 a.	Slight trems.	... ...	57.0	448.1	Fine.	$\frac{1}{4}$	$\frac{4}{6}$	$\frac{2}{3}$
28	... ...	* Slight trems.	3 p. slight quake.	61.8	292.0	Fine.	$\frac{1}{2}$	$\frac{3}{3}$	$\frac{2}{2}$
29	Slight trems.	... ...	... ...	63.6	291.0	Fine.	$\frac{2}{2}$	$\frac{2}{2}$	$\frac{1}{2}$
30	Slight trems. 5 p.	... ...	... ...	66.8	264.7	Fine.	$\frac{0}{2}$	$\frac{2}{2}$	$\frac{1}{0}$
31	Slightly irregular.	Slight trems.	... ...	65.9	235.7	Fine.	$\frac{1}{1}$	$\frac{3}{1}$	$\frac{1}{1}$
April 1	Slight trems.	* Slight trems.	3 a. slight quake.	60.5	197.1	Fine.	$\frac{1}{1}$	$\frac{2}{3}$	$\frac{1}{3}$
2	Slight trems.	* Slight trems.	... ...	63.8	303.3	Fine.	$\frac{2}{3}$	$\frac{3}{4}$	$\frac{1}{1}$
3	Slight trems.	Wavy.	... ...	68.0	231.7	Fine.	$\frac{0}{1}$	$\frac{2}{2}$	$\frac{3}{2}$
4	Slight trems. 3 p.-9 p.	Slight trems.	... ...	64.2	465.8	Fine.	$\frac{0}{2}$	$\frac{2}{4}$	$\frac{3}{3}$
5	Slightly wavy.	Trems. max. at midnight, 2m.	... ...	57.8	638.9	Dull, calm.	$\frac{4}{4}$	$\frac{3}{4}$	$\frac{3}{3}$
6	10 a.-3 p. trems. of 2mm.	Trems.	... ...	57.3	440.9	Windy.	$\frac{1}{6}$	$\frac{3}{6}$	$\frac{2}{3}$
7	... ...	* Slight trems.	... ...	67.4	357.2	Fine.	$\frac{1}{3}$	$\frac{3}{3}$	$\frac{2}{2}$
8	Slight trems.	Slight trems.	... ...	65.4	238.1	Damp.	$\frac{1}{1}$	$\frac{2}{5}$	$\frac{1}{3}$

	North-South Component.	East-South Component.	Earthquakes.	Barometer reduced 0° C. at sea level +700.	24 hours velocity of wind.	Remarks.	Wind Intensity Barometer Gradient.		
							6 a.m.	2 p.m.	9 p.m.
April					Kilo.				
9	Slight trems. 1mm.	Slight trems. at 1 a. 2m. up to 1 p.	... ...	61.6	477.9	Windy.	$\frac{1}{5}$	$\frac{3}{5}$	$\frac{0}{2}$
10	Slight trems. all day.	Slight trems.	... ...	62.5	471.4	Fine.	$\frac{1}{1}$	$\frac{4}{1}$	$\frac{3}{3}$
11	4 a.-5 p. large trems. at 5 p. trems. 6 or 7mm.	9 a.-5 p. large trems. max. at 4-5 p. 5m.	... ...	55.4	672.7	Windy. S. warm wind.	$\frac{3}{2}$	$\frac{3}{5}$	$\frac{2}{3}$
12	1 p.-5 p. slight trems.	1 p.-5 p. slight trems.	... ...	61.5	251.8	Still.	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{2}{2}$
13	... ...	Not working.	5.54.0 a. $\frac{\cdot 7}{1.4}$	58.3	280.6	... ...	$\frac{1}{2}$	$\frac{2}{1}$	$\frac{0}{2}$
14	2-10 p. slight trems.	Slight trems.	... ...	60.1	222.0	Still.	$\frac{2}{2}$	$\frac{2}{2}$	$\frac{1}{1}$
15	10 a. slight trems. two small waves at 5 p.	Slight wavy.	... ...	64.3	247.8	Still.	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{3}$
16	Slight trems.	Morning trems.	... ...	64.7	317.8	Still.	$\frac{2}{3}$	$\frac{3}{3}$	$\frac{2}{3}$
17	From noon to 5 p. slight trems.	* Slight trems.	... ...	54.3	417.5	Heavy rain and wind last night.	$\frac{3}{3}$	$\frac{3}{3}$	$\frac{3}{3}$
18	11-12 a. slight wavy.	No trems.	... ...	58.3	205.1	Rain.	$\frac{0}{3}$	$\frac{2}{2}$	$\frac{1}{3}$
19	11-12 a. pulsations about 3m. another from 3-5 p.	No trems.	... ...	58.0	229.3	Dull and still.	$\frac{2}{2}$	$\frac{1}{1}$	$\frac{1}{1}$
20	10 p. to midnight 2mm. trems.	10 p. to midnight trems. 4mm.	... ...	59.7	282.4	Fine, rain at night.	$\frac{1}{3}$	$\frac{3}{3}$	$\frac{1}{1}$

21	Slightly wavy.	Trems. cease at 2 a.	... ...		64.8	183.4	Fine.	1/3	2/3	2/2
22	No trems.	Slightly wavy.	... ...		67.3	333.9	Fine.	1/3	2/3	0/2
23	No trems.	At 5 a. a deflection.	4.22.22 a.	·3/1.8	69.7	257.4	Fine.	0/1	3/2	2/1
24	Not working.	... ...	... ...		66.5	534.2	Fine.	1/2	4/3	3/4
25	1 a. trems.	* No trems.	... ...		62.0	796.7	Windy.	2/5	3/3	3/1
26	8 a. large trems 3mm.	1 a. large trems. 2m., at 8 a. 3m.	... ...		62.6	412.0	Fine.	3/5	3/5	1/2
27	3 p. a 2mm. pulse again at 5 p.	No trems.	... ...		68.3	282.4	Fine.	1/1	1/1	1/1
28	... ...	* Slight trems.	... ...		67.3	316.2	Rain, no wind.	2/3	2/2	2/2
29	2 p.-7 p. slight trems.	Slight trems. 2-7 p.	... ...		68.4	331.5	Dull, no wind.	2/3	3/3	1/3
30	From noon 2mm. trems. to 7 p. and continuous to next day.	From noon 2mm. trems. to 9 p. and continuous to next day.	... ...		66.9	385.4	Dull, no wind.	3/4	2/4	2/5
May.										
1	Slight trems. 10 a.-7 p.	Slight trems.	... ...		57.5	502.0	Dull, no wind.	3/5	2/1	3/2
2	8 p.-9 p. slight trems.	Slight trems.	... ...		54 9	444.1	Fine, windy.	2/3	2/5	1/4
3	All day slightly wavy.	Wavy and slight trems.	Noon.		62.1	407.1	Fine, no wind.	3/5	0/4	2/2
4	All day slightly wavy.	Wavy and slight trems.	... ...		66.4	173.8	Fine, dull.	1/2	2/1	1/2
5	... ...	No trems.	... ...		58.8	437.6	Dull, threatens rain.	2/1	3/3	1/2
6	Trems. 2-4 p. of 3mm.	Trems. 2-4 p. of 3mm.	Quake 4 p.		54.9	432.7	Dull, rain, no wind.	1/1	1/2	1/3
7	2 a.-4 p. trems. when a pulse of 4mm and a record of 3mm.	Slight trems.	... ...		52.7	224.5	Dull, rain.	3/5	1/5	1/3

	North-South Component.	East-South Component.	Earthquakes.	Barometer reduced 0° C. at sea level +700.	24 hours velocity of wind.	Remarks.	Wind Intensity Barometer Gradient.		
							6 a.m.	2 p.m.	9 p.m.
May.					Kilo.				
8	Not working.	Not working.	10.14.0 p. $\frac{2.8}{.4}$	61.2	301.7	Fine.	...	...	...
9	Noon pulse 4mm. again at 5 p.	* Slight trems.	3.10.0 p. $\frac{.3}{2.2}$	67.6	272.7	Fine, no wind.	$\frac{1}{3}$	$\frac{2}{2}$	$\frac{2}{2}$
10	At 4 p. large pulse 6mm. at 2 p. smaller pulse.	No trems.	... ...	68.8	224.5	Fine, no wind.	$\frac{0}{2}$	$\frac{2}{1}$	$\frac{1}{2}$
11	Not working.	Not working.	9.30 a. quake. 2.31.58 p.	66.0	450.5	Fine, no wind.	...	...	...
12	... ...	No trems,	11.43.49 a. 0.4	64.3	355.6	Fine, no wind.	$\frac{0}{1}$	$\frac{3}{2}$	$\frac{2}{1}$
13	... ...	Slight trems.	... ...	61.8	743.5	Fine, S. wind moderate but became a heavy gale until 4 a.m. on the 14th.	...	...	...
14	... ...	... ...	... ...	59.7	484.3	... ...	...	...	...

Note.—The above notes for 1886 of *slight* trems. prefixed by an asterisk were intercalated in the list from a second careful examination of the records, after most of the succeeding analyses were made. They are, however, included in the last analysis relating to the occurrence of tremors and the wind, which is the most important analysis.

(*a.*) General Barometric Analysis.

The following table gives the actual number of times that tremors have been observed with the barometer standing above the monthly mean and when it was below that mean :—

	High Barometer.		Low Barometer.			
1885.	Trems.	No Trems.	Trems.	No Trems.	Trems. Totals.	Remarks.
January from 16th	6 ...	5 ...	8 ...	0 ...	14 ...	
February ...	6 ...	6 ...	7 ...	9 ...	13 ...	
March	6 ...	10 ...	11 ...	4 ...	17 ...	
April	4 ...	11 ...	6 ...	9 ...	10 ...	
May	4 ...	13 ...	5 ...	9 ...	9 ...	
June	4 ...	9 ...	0 ...	17 ...	4 ...	The Bar. was often very low, but there were no tremors.
July.....	1 ...	16 ...	3 ...	11 ...	4 ...	
August	2 ...	13 ...	4 ...	12 ...	6 ...	
September ...	3 ...	13 ...	6 ...	8 ...	9 ...	
October	5 ...	12 ...	5 ...	9 ...	10 ...	
November ...	3 ...	12 ...	8 ...	7 ...	11 ...	
1886.						
January from 20th.....	1 ...	2 ...	4 ...	2 ...	5 ...	Not a complete [month.
February ...	3 ...	10 ...	13 ...	1 ...	19 ...	
March	6 ...	8 ...	8 ...	3 ...	14 ...	
April	13 ...	2 ...	13 ...	2 ...	26 ...	[month.
May	5 ...	8 ...	4 ...	1 ...	9 ...	Not a complete
	72	143	105	105		

This table shows that tremors are oftener observed with a low barometer than with a high barometer, but although the barometer may be low it is just as likely that there should be no tremors as it is that tremors should be observed.

With a high barometer it is more likely that tremors should not occur.

The column showing the number of times that tremors were observed each month shows that these movements are more numerous in winter than in summer. This is a result which I have previously published, and which has been emphasized by the Italian observers.

(*b.*) General Wind Analysis.

The following table shows the number of times each month that tremors were observed or were not observed for different intensities of the wind. The intensity of the wind is indicated in kilometers per 24 hours. To obtain the actual number of kilometers the numbers given at the head of each column must be multiplied by 100. Thus 1-1.5 means that the wind velocity was from 100 to 150 kilometers per 24 hours. T means tremors and N T means no tremors.

The general conclusions to be drawn from this table are :—

1. When the wind was high tremors were almost invariably observed.

2. When the wind velocity was small it was seldom that tremors were observed.

There two results are perhaps more clearly indicated in the last line, which shows the number of times that tremors were observed as a percentage of the total numbers of observations made for each particular wind velocity.

	1-1.5		1.5-2		2-2.5		2.5-3		3-3.5		3.5-4		4-4.5		4.5-5		5-5.5		5.5-6		6-6.5		6.5-7		7-7.5		7.5-8	
	T	NT	T	NT	T	NT	T	NT	T	NT	T	NT	T	NT	T	NT	T	NT	T	NT	T	NT	T	NT	T	NT	T	NT
January	—	—	1	3	1	4	1	1	—	1	—	3	1	—	—	1	—	—	—	1	—	—	—	1	—	—	—	—
February	—	—	—	1	1	1	5	4	2	3	1	1	—	1	—	1	2	2	1	—	—	1	—	—	1	—	—	—
March	—	1	—	1	—	4	4	2	5	1	—	1	2	2	1	1	1	1	1	—	—	—	1	—	1	—	1	—
April	—	1	1	2	—	2	1	4	3	3	3	2	1	—	2	—	2	1	—	1	—	1	—	—	—	—	—	—
May	—	—	—	1	1	2	2	5	1	4	3	2	1	4	—	2	—	1	—	—	—	—	—	—	1	—	1	—
June	—	4	—	3	2	10	1	5	—	1	—	—	—	—	—	1	—	1	—	—	1	1	—	—	—	—	—	—
July	—	1	—	4	—	9	—	2	—	4	1	2	1	2	—	—	—	2	—	—	—	1	2	—	—	—	—	—
August	—	—	1	3	—	7	—	6	3	2	—	2	1	1	—	—	—	2	—	—	—	1	—	1	1	—	—	—
September	—	1	3	1	2	12	1	3	2	1	—	—	—	—	—	—	—	2	1	—	—	—	—	1	—	—	—	—
October	2	1	—	1	—	7	4	7	4	2	—	1	—	—	1	—	—	—	—	—	1	—	—	—	—	—	—	—
November	—	—	2	6	2	6	2	3	—	1	2	1	2	1	1	—	1	—	—	—	—	—	—	—	—	—	—	—
Jan. and Feb.	2	—	4	2	6	3	—	2	5	3	1	4	2	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—
March	—	1	—	1	2	1	4	3	3	2	—	1	1	1	—	—	1	—	—	—	1	—	1	—	—	—	1	—
April	—	—	—	2	5	1	2	3	3	2	1	1	3	—	3	—	—	1	—	—	1	—	1	—	—	—	1	—
May	—	—	—	1	1	1	—	1	—	—	—	1	3	1	—	—	1	—	—	—	—	—	—	—	1	—	—	—
Totals	4	10	12	32	23	70	27	51	31	30	12	22	18	15	8	6	8	13	3	2	4	5	5	3	5	—	4	—
Percentage of tremors ...	28	—	27	—	24	—	34	—	50	—	35	—	54	—	57	—	38	—	60	—	44	—	62	—	100	—	100	—

(*c.*) Detailed Wind Analysis.

The following analysis refers to a period between January 20th and May 14th, 1886, or nearly four months. The wind observations were tri-daily, and, as already mentioned, are the observations made at the Imperial Meteorological Observatory.

In the following table the number of times that tremors were observed and the number of times that tremors were not observed are given for each degree of wind.

	0		1		2		3		4		5		6		
1886.	T.	NT.	T.	NT.	T.	NT.	T.	NT.	T.	NT.	T.	NT.	T.	NT.	
Jan. 20—Feb. 28.....	5	7	17	20	20	22	9	4	2	...	...	...	...	...	
March	2	2	13	11	16	9	5	5	6	0	...	...	...	...	
April	2	5	16	12	13	13	17	5	3	1	...	...	...	...	
May 1—14th	1	2	7	4	5	5	6	2	1	0	...	...	...	...	
Total	10	16	53	47	54	49	37	16	12	1	...	...	...	...	=295

In looking at the general result of the wind analysis it is seen that there may be times with the wind in any state when there are either tremors or no tremors.

The percentage of cases in which tremors have been observed at different states of the wind are as follows:—

With no wind, tremors were observed in 38 per cent. of the number of times of observation.
With the wind at 1°, tremors were observed in 53 per cent. of the number of times of observation.
With the wind at 2°, tremors were observed in 53.4 per cent. of the number of times of observation.
With the wind at 3°, tremors were observed in 70 per cent. of the number of times of observation.
With the wind at 4°, tremors were observed in 92 per cent. of the number of times of observation.

From this we see that the stronger the wind the greater is the likelihood of tremors occurring, from which we might conclude that many of the tremors which have been observed are a consequence of the wind. The difficult question which here arises is why there should be so many cases when tremors have not been observed. And more particularly why they should occur when there has been a calm. Answers to these questions are apparently found when we enquire into the state of the barometric gradient at the different states of the wind,

when it is seen that the average barometric gradient at each particular state of the wind when tremors have occurred has invariably been steeper than the gradient for the same intensity of wind when tremors have not occurred. These results are shown in the following table. The number of cases for each particular state of the wind which have been used when calculating the average barometric gradient, are these given as totals in the last line of the wind analysis table:—

	With Tremors.	Without Tremors.
With the wind at 0 the average barometric gradients were...	2·3	and 1.9
With the wind at 1° the average barometric gradients were...	2.9	and 2.1
With the wind at 2° the average barometric gradients were...	3.0	and 2.1
With the wind at 3° the average barometric gradients were...	3.6	and 2.9
With the wind at 4° the average barometric gradients were...	4.4	and 3.0

Although the number of observations which were made when the wind had an intensity of 4 are small, the above table apparently shows that tremors are more intimately connected with barometric gradients than they are with the force of a local wind.

(*d.*) Detailed Barometric Analysis.

These observations led me to make a direct comparison between the occurrence of tremors and the barometric gradient irrespective of the state of the wind. The result of such comparisons are given in the following table. In the upper line the gradient is indicated in millimeters per 120 geographical miles. Beneath each gradient the number of hours that tremors were observed are given in a column marked T and the number of hours that tremors were not observed are given in the column marked N.T.

When the gradient was zero it is seen that tremors were observed but seldom, while when the gradient was high tremors were always observed.

Bar. gradient in millimeters per 20 miles.	0		1		2		3		4		5		6		7		8		9	
	T.	N.T.	T.	N.T.	T.	N.T.	T.	N.T.	T.	N.T.	T.	N.T.	T.	N.T.	T.	N.T.	T.	N.T.	T.	N.T.
Jan. 20—Feb. 28..	0	5	7	7	11	23	10	12	12	2	9	5	1	0	...	...	...	...	1	0
March	1	1	10	2	15	11	6	11	3	0	2	2	2	0	3	0	...	...	...	...
April	0	0	4	8	11	13	18	15	6	1	9	1	2	0	...	...	...	...	...	...
May	1	2	7	4	5	5	6	2	1	0	...	...	...	...	...	...	...	...	...	...
Total	2	8	28	21	42	52	40	40	22	3	20	8	5	0	3	0	...	...	1	0=295

A clearer idea of the meaning of this table is obtained when we consider the percentages of cases in which tremors were observed for observations made with each particular gradient.

These percentages run as follow :—

With a gradient of zero tremors were observed in 20 per cent. of the observations.
With a gradient of 1mm. tremors were observed in 57 per cent. of the observations.
With a gradient of 2mm. tremors were observed in 44 per cent. of the observations.
With a gradient of 3mm. tremors were observed in 50 per cent. of the observations.
With a gradient of 4mm. tremors were observed in 88 per cent. of the observations.
With a gradient of 5mm. tremors were observed in 71 per cent. of the observations.
With a gradient of 6mm. tremors were observed in 100 per cent. of the observations.
With a gradient of 7mm. tremors were observed in 100 per cent. of the observations.
With a gradient of 9mm. tremors were observed in 100 per cent. of the observations.

Although the last three results may on account of the fewness of the observations on which they are founded be left out, the general result towards which the table indicates, is that tremors are proportionately more frequent with a high barometric gradient than with a low gradient. From this alone it might be argued that tremors were probably the result of wind, which usually accompanies a high gradient. It has, however, been shown for all intensities of wind that the average gradient when tremors occurred was always greater than when they were absent.

(*e.*) THE PRESENCE OF TREMORS AND ABSENCE OF WIND.

By referring back to page 50 it will be seen that during four months tremors were observed in Tokio ten times when there was practically a calm and fifty-three times when there was a light breeze indicated as unity. With the wind in these same conditions it has also been shown that the barometric gradient was relatively high. This has led me to enquire whether there might not have been a strong wind blowing somewhere near

Tokio, although in Tokio itself wind was practically absent. The excellent tri-daily charts published under the superintendance of Mr. E. Knipping have enabled me to make such investigations, and with the following result:—

The following notes describe the state of the weather, particularly the wind, at places from 50 to 200 miles distant from Tokio while in Tokio itself there was a calm or only a gentle breeze but at the same time earth tremors.

1. WITH THE WIND IN TOKIO AT ZERO.

1. February 6th and 7th.—In Tokio tremors from midnight to midnight, being particularly *strong* at 4 a.m. on the 7th.
   In Tokio the wind at 6a.=0, 2p.=3, 9p.=0 and at 6a. on the 7th=0. On the 6th on Shikoku 260m. to S.W. wind =4 and on the 7th at 6a., a strong S.W. wind 100 to the S.W. and generally a strong S.W. wind blowing up Japan.
2. February 10th.—In Tokio tremors slight.
   In Tokio wind at 6a.=0, 2p.=2, 9p.=0.
   On the previous night, when in Tokio the wind was 1, there was a strong S.W. wind at Kobe blowing up Japan.
   At 2p. strong S.W. wind of 3° blowing up Japan.
   At 9p. strong S.W. wind of 3° blowing up Japan 60 miles to S.W. of Tokio.
3. February 11th.—In Tokio tremors slight.
   Wind in Tokio at 6a.=2, 2p.=2, 9p.=0.
   At 2p. 120m. to S.W. wind of 4 blowing up Japan, at 60 miles to S.W. wind=3 also blowing up Japan, and at 9p. the same.
4. February 25th.—In Tokio tremors sight.
   Wind in Tokio 6a.=2, 2p.=0, 9p.=0.
   In central Japan there was a calm from 2 to 9p.
5. March 16th.—In Tokio slight tremors.
   Wind in Tokio 6a.=1, 2p.=1, 2p.=0.
   At 2p., 60 miles S.E., wind=3 and 120m. North S.E. wind =3.
   At 9p. very light winds in central Japan.

6. March 30th.—In Tokio slight tremors about 5p.
   In Tokio wind 6a.=0, 2p.=2, 9p.=1.
   At this time the wind in central Japan was very slight.
7. April 3rd.—In Tokio slight tremors.
   In Tokio wind 6a.=0, 2p.=2, 9p.=2.
   At this time the wind in central Japan was slight.
8. April 9th.—In Tokio tremors 1 mm.
   Wind in Tokio 6a.=1, 2p.=3, 9p.=0.
   At 120 m. to S.W. the wind at 6 a.=4 and at 2 p.=4, but at night there was a general calm. On April 8th, however, there was a strong wind 120m. to the N.W.
9. May 3rd.—In Tokio wavy line all day.
   Wind in Tokio 6a.=3, 2p.=0, 9p.=2.
   At 6a. and 2p. 60 to 120m. to S.W. wind=3.

From the above we see that in cases 1, 2, 3, 5, 8, and 9 there were strong winds blowing against the ranges of mountains which shelter the Tokio plain on its western and northern sides. The question then arises whether these mountains by being shaken cause tremors to be propagated, either in the surface or beneath the surface to Tokio.

In cases 4, 6, and 7 there does not appear to have been any wind either in Tokio or Japan which could have produced tremors. The tremors on such occasions in Tokio were, however, very slight.

2. With the Wind in Tokio at 1.

1. January 21st.—In Tokio tremors slight at 10p.
   Wind in Tokio 6a.=1, 2p.=3, 9p.=1.
   At 6a. 120m. to N. and N.W. wind=4.
   2p. 60m. to 120m. to S.W. wind=4 and 5.
   9p. 60 to 120m. to N. and W. wind=4.
2. January 23rd.—In Tokio slight tremors at 10a.
   Wind in Tokio 6a.=2, 2p.=1, 9p.=1.
   At 6a. 120m. to S.W. wind=2.
   2p. 120m. to S.W. wind=3.

3. January 31st.—In Tokio slight tremors all day.
   Wind in Tokio 6a.=2, 2p.=2, 9p.=1.
   All day wind of 3—4 to the S.W.
4. February 1st.—Slight tremors.
   Wind in Tokio 6a.=2, 2p.=1, 9p.=1.
   All day wind to S.W. and N.W. 4—5.
5. February 7th.—Tremors particularly strong at 4a.
   Wind in Tokio 6a.=0, 2p.=1, 9p.=1.
   All day to North and Westward a gale of 3—4.
6. February 8th.—Slight tremors.
   Wind in Tokio 6a.=3, 2p.=1, 9p.=2.
   All day to South and West a gale of 4.
7. February 9th.—Slight tremors especially at 4p.
   Wind in Tokio 6a.=3, 2p.=1, 9p.=1.
   All day a gale to South and West.
8. February 12th.—Slight tremors.
   Wind in Tokio 6a.=2, 2p.=3, 9p.=1.
   6a. gale to S.W. 2p. gale to S.W.
   9p. gale to N.W.
9. February 13th.—Slight tremors.
   Wind in Tokio 6a.=1, 2p.=3, 9p.=1.
   6a. gale to West and S.W.
10. February 14th.—Slight tremors.
   Wind in Tokio 6a.=1, 2p.=2, 9p.=2.
   To the westward wind=3.
11. Feb. 22nd.—Slight tremors.
   Wind in Tokio 6a.=1, 2p.=1, 9p.=1.
   At 6a. a calm in central Japan, but at 2p. and 9p. to the W. and S.W. a gale.
12. Feb. 26th.—Tremors moderately strong at 3a.
   Wind in Tokio 6a.=1, 2p.=2, 9p.=2.
   At 6a. calm generally in Japan, at 2p. and 9p. to S.W. wind =3.

From the above we see that during February, with every case, excepting perhaps the last, although there have been tremors in Tokio when it was practically calm, within 50 to 150 miles

of Tokio there has been a strong gale. The direction of this wind has usually been from the S.W. up towards Tokio.

13. March 2nd.—Exceedingly small tremors.
Wind in Tokio 6a.=1, 2p.=2, 9p.=2.
6a. calm in central Japan, 2p. and 9p. West coast=4.

14. March 6th.—Slight tremors.
Wind in Tokio 6a.=2, 2p.=2, 9p.=1.
At 6a. and 2p. on West coast 3 and 4 but at 9p. calm.

15. March 16th.—Slight tremors.
Wind in Tokio 6a.=1, 2p.=1, 9p.=0.
6a. to North 3 and at 2p. to North and West 3.

16. March 22nd.—Slight tremors.
Wind in Tokio 6a.=2, 2p.=2, 9p.=1.
At 6a. to S.W. 3, at 2p. and 9p. Central Japan 1 and 2.

17. March 25th.—Slight tremors.
Wind in Tokio 6a.=1, 2p.=1, 9p.=1.
6a. and 2p. to S.W. 3 and at 9p. calm in Central Japan.
On the previous day in Tokio and in Central Japan there had been a heavy gale.
These tremors may therefore have been due to the wind on the day previous.

18. March 27th.—Slight tremors from 2a. to 8p. Max. at 8a.
Wind in Tokio 6a.=1, 2p.=4, 9p.=2. At 6a. to S.W. from 60 to 120 miles a wind 3. This was a gale which from the day previous had been working up Japan. As this wind is not recorded in Tokio until 2p. on the 27th, it would appear that the tremors out-raced the wind by 10 hours. The tremors in Tokio died out at about the same time that the wind died.

19. March 29th.—Slight tremors.
Wind in Tokio 6a.=2, 2p.=2, 9p.=1.
6a. calm in Central Japan. 2p. heavy gale to West and South-west, 9p. calm.

20. March 30th.—Slight tremors at 5p.

Wind in Tokio, 6a.=0, 2p,=3, 9p.=1.

6a. to North 3, otherwise calm, 2p. to North and N.W. 3 and 4, at 9p. generally calm.

21. March 31st.—Slight tremors.

Wind in Tokio 6a.=1, 2p.=3, 9p.=1.

6a. generally calm, 2p. wind strongest in Tokio.

9p. generally calm.

During this month there are only three cases (Nos. 16, 20, and 21) where tremors do not appear to be related to a distant wind.

22. April 2nd.—Slight tremors.

Wind in Tokio 6a.=2, 2p.=3, 9p.=1, at 2p. to North and South 3 and 4. 9p. to North 4.

23. April 6th.—From 10a. to 3p. tremors 2mm.

Wind in Tokio 6a=1, 2p=3, 9p=2.

At 6a, to S.W. 4 and to N. 5 ; 2p to S.W. 4 and N. 4.

On the 5th the wind in Tokio had been strong.

24. April 8th.—slight tremors.

Wind in Tokio 6a=1, 2p=2, 9p=1.

6a. in Central Japan wind 1 and 2, 9p. to W. 3 and to N. 3.

25. April 9th.—Tremors 1mm.

Wind in Tokio 6a=1, 2p=3, 9p=0.

6a. to S.W. 4 to N. 3.

26. April 10th.—Slight tremors.

Wind in Tokio, 6a=1, 2p=4, 9p=3.

6a. wind generally 1.

27. April 12th.—1p.-5p. slight tremors.

Wind in Tokio 6a=1, 2p=1, 9p=2.

6a. generally 1 or 2, 2p. to W. 3.

28. April 14th.—2-10p. slight tremors.

Wind in Tokio 6a=2, 2p=2, 9p=1.

2p. to W. 3, 9p. generally 1 and 2.

29. April 15th.—At 10a slight tremors.

Wind in Tokio 6a=1, 2p=1, 9p=1.

6a. generally 1 and 2, 2p. generally 1, 2 and 3.

30. April 20th.—10p. to midnight tremors 2 mm.
Wind in Tokio 6a=1, 2p=3, 9p=1.
2p. to W. 3, 9p. generally 1 and 2.

31. April 26th.—At 8a. tremors 3 mm.
Wind in Tokio 6a.=3, 2p.=3, 9p.=1.
Up to 2p. wind generally 3 and 4, 9p. generally 1 and 2.

32. April 29th.—From 2-7p. slight tremors.
Wind in Tokio 6a=2, 2p.=3, 9p =1
At 9p. to W. and N. 3.

33. May 2nd.—8 to 9 p. slight tremors.
Wind in Tokio 6 a.=2, 2 p.=2, 9 p.=1.
9 p. to W. and N. 4. The wind was from the west and next morning reached Tokio.

34. May 4th.—Slightly wavy.
Wind in Tokio, 6 a.=2, 2 p.=2, 9 p.=1.
6 a. and 9 p. generally 1 and 2.

35. May 6th.—From 2-4 p. tremors 3mm.
Wind in Tokio 6 a.=1, 2 p.=1, 9 p.=1.
At 2 p. and 9 p. to N.W. 3.

36. May 7th.—From 2 a.-4 p. tremors.
Wind in Tokio 6 a. =3, 2 p.=1, 9 p.=1.
At 2 p. to W. 3 and at 9 p. to W. 4.

In the above epitome for the months of April and May it appears that there are not more than three or four cases in which tremors have been recorded in Tokio which are not explicable on the assumption that they may not have resulted from the effects of wind.

The general conclusions which I arrive at are, first, that there were 45 days on which tremors were observed in Tokio, when there was an extremely light breeze or a calm. Second, that on 10 of these days there appears to have been a calm in Central Japan, and, therefore, assuming the observations to be correct, the tremors which were observed cannot be explained as being a result of wind. Third, on 35 days, although it was calm in Tokio there was a strong wind blowing within 50 or

150 miles of Tokio. When the wind was blowing up Japan from the S.W. the tremors were very marked.

If instead of analysing the wind analysis, the table of barometric gradients are taken where tremors have occurred, where the gradient has been 1 or zero it will be found that nearly all these cases are contained in the above list and they form the exceptional cases, that is those where the existence of tremors cannot be explained on the assumption of a high gradient or the wind.

I have also examined the cases where there were no tremors in Tokio and no wind.

The dates and times of these cases are as follows:—

February 6th, 6a.—20, 9p.—24, 9p.—27, 9p.
March 21st, 9p.—26, 6a.
April 4th, 6a.—13, 9p.—18, 6a.—23, 6a.
May 10th, 6a.—12, 6a.

In all these instances there was general calm in Central Japan. A partial exception was on February 27th, at 9p. when 60 miles to the S.W. of Tokio, there was a light wind blowing towards the West, against a wind of 3 blowing 120 miles to S.W. towards the East.

Farther, I have examined the cases where there were no tremors in Tokio and only a gentle breeze of force 1.

The dates and times of these cases are as follows:—

January 25th, 9p.
February 3rd, 9p.—4, 6a.—5, 6a. and 9p.—9, 6a.—15, 2p. and 9p.—16, 2p. and 9p.—17, 6a.—18, 9p.—19, 6a. and 2p.—27, 2p.
March 1st, 9p.—3, 6a.—12, 6a. and 9p.—15, 9p.—17, 6a.—21, 6a. and 2p.—26, 2 and 9p.—28, 6a.
April 1st, 6a and 9p.—7, 6a.—13, 6a.—17, 9p.—18, 9p.—19, 2 and 9p.—20, 6a.—21, 6a.—22, 6a.—24, 6a.—27, 6a., 2p. and 9p.
May 5th, 9p.—6, 6a.—9, 6a.—10, 9p.

Out of these 44 cases I find that in 22 of them there was a general calm in Central Japan, while in the 22 which remain there was a breeze of force 2 in *one* or *two* places only and this often blowing in contrary directions.

The general conclusion is that the absence of tremors in Tokio indicates a general calm in Central Japan. Later on it will be shown that tremors are sometimes absent in Tokio if the wind blows inland from the ocean.

(*f*). Absence of Tremors with Wind.

From page 50 it will be seen that there have been sixteen cases in Tokio when there was a wind of strength 3, and one case with the wind at 4, when there were no tremors recorded. To find an explanation for these conditions I have drawn up the following table, indicating the state of wind in Central Japan on the dates when these observations were made :—

January 21st.—Machine started but stopped.

January 22nd.—Machine stopped.

February 6th.—At 6a. calm, at 2p. at Tokio wind from S. but otherwise calm in Central Japan, at 9p. calm.

February 9th.—At 6a. wind in Tokio not 3 but 1, but wind coming up from S.W.

February 15th.—In Tokio 3 from N.W. but in Central Japan calm.

February 20th.—In Tokio 3 from N. but in Central Japan calm.

February 28th.—In Tokio 3 from S. but in Central Japan 2 and 3 in various directions. In this case it would appear that there ought to have been tremors in Tokio.

March 1st.—In Tokio wind 3 from S. but in central Japan calm, except Niigata where a wind 3 blows to E.

March 3rd.—In Tokio at 2p. wind 3 from N.W. but on the N. and N.W. sides of the island it was calm, therefore the wind was local, at 9p. the same.

March 17th.—In Tokio at 2p. wind from S.E., at Niigata a parallel wind, otherwise calm.

March 28th.—In Tokio 2p. wind from S.E. but to the West and North there is a westerly wind of 3 and 4. This ought to have produced tremors.

April 7th.—In Tokio 2p. wind 3 from S. In other parts of Central Japan 1 and 2.

April 23rd.—In Tokio 2p. wind 3 from N.W., otherwise calm.

April 24th.—In Tokio at 2p. wind of 4 from south; a wind of 2 and 3 also from the ocean to the southward. In the north calm.

At 9p. in Tokio, and 50 miles south, from S.W. In other places it is blowing to North-West. In this latter case we might have tremors.

May 5th.—In Tokio, and 50 miles to S.W., wind of 3 from the S. and S.W. otherwise calm.

May 12th.—In Tokio and 50 miles to S.W. wind 3 from S.E. and S. otherwise calm.

From an analysis of the above notes it appears that in two of the cases when there was a strong wind in Tokio and no tremors were observed, the recording instrument was not in action. In three instances (February 28th, March 28th, and April 24th) it seems that if tremors are the result of wind tremors ought to have been recorded. In three other cases (February 15th, March 3rd, and April 23rd) the wind in Tokio was local. In the remaining cases the wind was from the ocean (S.E., S., or S.S.W.) These latter cases are the majority.

We might therefore conclude that local winds or winds from the ocean do not produce tremors in Tokio.

However we must not overlook the fact that in six out of the 12 cases where tremors occurred with a wind 4, the conditions were in many respects similar to the case (April 24th) when tremors did not occur. Perhaps there may be an error in the records for this particular day.

(*g*). Analysis of a Few Selected Storms.

In the accompanying five diagrams five microseismical storms are graphically illustrated in conjunction with barometrical

changes and the fluctuations of the wind. The horizontal scale is that of mm. measured in hours. The curve showing tremors is marked T. and the intensity of the tremors is measured vertically, each line representing one millimeter. These millimeters are actual distances measured from the breadth of the band of perforations on the strip of paper on which the records were made. The curve marked W. shows the varying intensity of the wind measured in miles per hour? The curve B. shows the fluctuations of the barometer in millimeters.

1. April 10th.—The tremors were gentle for 15 hours, three hours after which they reached a maximum and in 12 hour more died away. During this time the barometer was rapidly falling. For the first 18 hours the wind curve follows that of the tremors, but the wind still continued high after the tremors had commenced to decrease. The wind when at its maximum was from the south. At 9 p., however, it was from the S.E. and low to the N.W.

2. April 20th.—Here we have a well marked storm lasting 3 hours, 10p. on April 20th to 1a. on April 21st. The barometer was rising and the wind was falling.

The barometer was low to the S. and high in the north. From the weather maps it does not appear to have been any wind which could cause these tremors.

The barometrical conditions, it will be observed, are the reverse of case 1.

3. April 25th and 26th.—The tremors began gently, took 12 hours to reach a maximum, which they retained for 6 hours and died away in 4 or 5 hours.

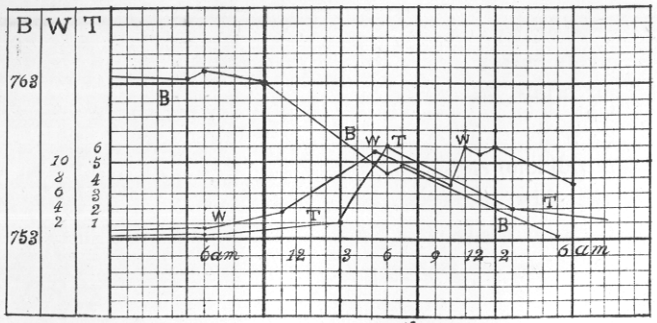
When the tremors were at a maximum the barometer was rising and the wind falling.

At 9p. on the 25th the wind was 3 from the south.

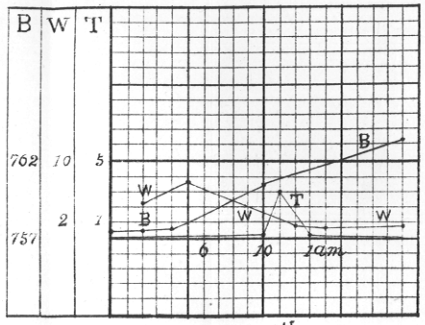
At 6a. on the 26th the wind was 3 from the north.

At 2p. on the 26th the wind was 3 from the south-east and strong winds to the S.W.

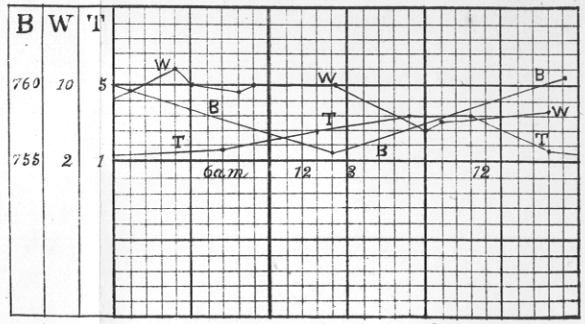
TREMOR STORMS IN 1886



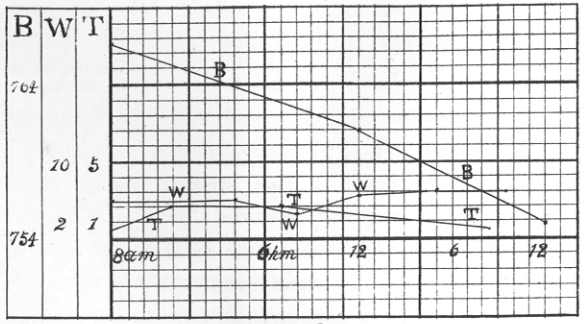
APRIL 10th



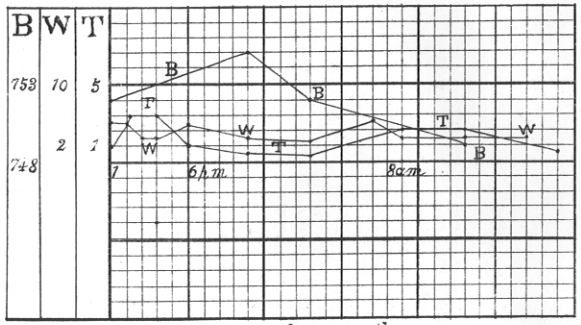
APRIL 20th



APRIL 25th AND 26th



APRIL 30th



APRIL 6th AND 7th

4. April 30th.—The wind and tremor curves agree fairly well and the barometer is falling. Strong winds from the N.W. and N. Central Japan generally windy.

5. May 6th and 7th.—The wind and tremor curves agree fairly well. At the maximum points on the tremor curves there are slight falls in the wind. During the storm the barometer rose and fell.

On the 7th the wind in Central Japan was tolerably strong.

The point of greatest interest connected with the above analysis is that they show the time over which microseismical storm may extend, which may be anything between 3 hours and 30 hours.

Sometimes they occur with a falling barometer and sometimes with a rising barometer.

Sometimes they agree with the wind and sometimes they have an existence when the wind is absent.

Disturbances like that of April 20th only appear to find an explanation on the assumption that they are of subterranean origin.

(*h.*) Tremors and Earthquakes.

From the fact that microseismical disturbances are more frequent during the winter months, which is the season when earthquakes are frequent, it might be assumed that earthquakes and tremors had a direct connection. From the preceding tables, however, it appears that earthquakes have occurred 53 times when there have been no tremors and 33 times when there have been tremors. From this we may at least conclude that earthquakes are as likely to occur without tremors as with them. If, however, the tremors which I have recorded could be classified into those which are of subterranean origin and those whose origin is due to surface disturbances produced by wind, it seems likely that a connection between earthquakes and the first of these groups might be discovered. Professor Rossi has certainly pointed out some remarkable instances where earthquakes have been preceded by

tremors, especially those when the movement has been vertical or intermittent. Vertical tremors, however, have not up to the present been investigated in Japan.

(*i.*) Earth Tremors and the State of the Wind in Central Japan in 1885.

I here propose to compare the occurrence of tremors which were recorded in 1885 with the state of the wind in Central Japan, by which I mean at places within 200 miles of Tokio, where the tremor observations were made. The material for making such comparisons is given in the three last columns for the year 1885. This material was derived from the tri-daily weather maps published by the meteorological department of this country. Through the kindness of that department, I am enabled to reproduce 15 of these maps as illustrations of the manner in which the analyses have been conducted. When the force of the wind in Central Japan has never exceeded 2, I have indicated this by zero. If at the station there should be a wind of force 3 or 4, while at the majority of the remaining stations the wind was at zero or 1, I have also indicated this as zero. If, however, the wind has a force of 3 or upwards at several stations, this is indicated by W. The letter W may, therefore, sometimes occur when in Tokio there has been a calm. It is evident that there will be a certain number of cases for which it is doubtful whether they should be indicated by W or by O,—that is, to say whether it was really windy in Central Japan taken as a whole, or whether it was calm. Local winds, that is to say, winds practically confined to Tokio, are indicated by the letters W.T., W.T. 3, or W.T. 4,—the numerals indicating the force of the wind.

Omitting three or four days in January when the instrument commenced to work and was a little irregular there are for 1885, 945 cases which may be examined. The results of the examination are as follows:—

1. With no wind and no tremors there are ..... 651 cases.
2. With no wind and tremors there are ..... 51 cases.

3. With wind and no tremors there are ..... 60 cases.
4. With wind and tremors there are..... 65 cases.
5. With local wind in Tokio and no tremors there are ..... 101 cases.
6. With local wind in Tokio and tremors there are ..... 17 cases.

On the assumption that tremors may in great measure be due to wind, the second and third results are difficult to understand. I have carefully re-examined these particular cases with the following results :—

(*a.*) The 51 Cases of Tremors unaccompanied by Wind.

In describing these cases, for convenience I have followed the Italians in using the two terms *seismic* and *baroseismic*. By tremors which may be *seismic* are meant those tremors which have occurred at times when there has neither been wind or any marked barometrical depression, or in other words, there has not been any obvious meteorological agency which might have produced such tremors. The *baroseismic* tremors are those which have accompanied a marked barometrical depression.

February (7 cases).—On the 1st and 2nd it is doubtful whether tremors occurred with the four cases of no wind. In two other cases the tremors were slight, and in one case there had been wind a few hours previously. As there was no marked barometrical depression on the 8th the tremors may be seismic.

Two cases may therefore be seismic and five doubtful.

March (6 cases).—On the 1st, 9p. there was wind a few hours previously. 2nd, 2p. a little wind and tremors slight, at 9p. seismic. 5th, 9p. tremors slight and short, seismic. 27th, wind before and after. 30th, tremors slight possibly baroseismic. Two cases may be seismic, one baroseismic, and three doubtful.

April (4 cases).—On the 5th, 6a. slight tremors for two hours, probably seismic.

17th, 9p. slight tremors for 1 hour, barometer low to S.W., therefore baroseismic.

20th, 6a. slight tremors for 3 hours, barometer low to S.W., therefore baroseismic.

30th, 9p. wind during previous 12 hours.

One case may be seismic, two baroseismic, and one doubtful.

May (5 cases).—On the 14th 9p. well defined tremors for 3 hours and barometer high, therefore seismic.

17th, 2p. wind before and after. 18th, 9p. wind during previous 12 hours and low barometer near Tokio. These tremors might either be due to wind or baroseismic. 26th, 6a. tremors slight and of short duration, probably seismic.

28th, 6a. and 2p. baroseismic.

Two cases may be seismic, two baroseismic, and one doubtful.

June (2 cases).—On the 20th, 6a. slight tremors for 2 hours, seismic.

30th, 9p. it is doubtful if tremors occurred that hour.

One case seismic and one case doubtful.

July (1 case).—July 18th, 9p. There was a low barometer over Tokio, but a few hours previously there had been wind. This case is therefore considered as being doubtful.

August (1 case).—August 31st, 9p. These tremors are not explicable either by the state of the wind or the barometer. The nature of the record confirms the idea that they are seismic.

September (6 cases).—On the 5th, 6a. the tremors were slight and there was wind immediately afterwards, therefore doubtful.

24th, 9p. tremors slight for 4 hours, possibly seismic.

25th, 9p. tremors slight for 1 hour, possibly seismic.

26th, 2p. tremors slight for 2 hours, possibly seismic.

27th, 6a. tremors slight for 2 hours, possibly seismic.

28th, 9p. tremors slight for 3 hours, possibly seismic.

Five cases are probably seismic and one case is doubtful.

October (11 cases).—On October 1st, at 2p. and 9p. tremors slight, seismic. 2nd, 6a. bar. somewhat low to the S., therefore baroseismic or seismic. 5th, seismic. 6th, 9p. trems. for 1 hour, seismic. 16th, 2p. and 9p.; shortly before these times there was a considerable barometric depression and a high wind. The tremors may therefore be due to wind or baroseismic. 24th, 6a. and 2p. baroseismic. 25th, 2p. seismic. 27th, 6a. trems. for 1 hour, seismic.

Six cases seismic, two baroseismic, three doubtful.

November (8 cases).—November 11th, 2p. slight trems. for 4 hours, seismic. 12th, 9p. might be due to previous wind, doubtful. 19th, 2p., 20th, 6a. and 2p., 22nd, 9p. and 23rd, 2p. seismic. 24th, 6a. baroseismic.

Six cases seismic, one baroseismic and one doubtful.

The 51 cases where tremors (which were almost invariably slight) were observed without wind may therefore be subdivided as follows:—In 26 instances the tremors, which were slight and of short duration, may be of subterranean origin. These are called seismic. In 8 instances the tremors have been accompanied by marked local barometrical depressions, while in 17 instances it is doubtful whether the tremors were or were not the result of wind.

(*b.*)—The 60 Cases of Wind and no Tremors.

February (9 cases).—In four cases the instrument gave a record in the form of a wavy line which might or might not mean tremors, in two cases the wind was general but its force did not exceed 2 and 3, and in one case the wind was only in the South.

In 7 cases it was therefore doubtful whether tremors ought to have been recorded, while two cases are inexplicable. Was the instrument working well on those occasions?

March (8 cases).—On the 3rd, 2p. wind moderate and of short duration.

March 9th, 2p.—Wind moderate and of short duration.

March 10th, 2p.—Wind moderate and of short duration.
March 13th, 2p.—Wind very moderate and of short duration.
March 18th, 2p.—Wind moderate and of short duration.
March 20th, 2p.—Wind local and of short duration.
March 25th, 2p.—Wind moderate and of short duration.
March 30th, 2p.—Wind moderate and of short duration.

In the last case there was a barometric depression over Tokio; and therefore there might have been baroseismic tremors. Seven cases may be explained on the assumption that local winds and winds of short duration do not cause tremors. The last case is inexplicable.

April (7 cases).—On the 8th 9p. ought to have been tremors. 9th 6a. wind chiefly local. 16th 9p., wind local. 21st 2p., 22nd 2p., 28th 2p. and 9p., wind moderate and of short duration, on the last very local.

Six cases are doubtful and one inexplicable.

May (10 cases).—On the 1st, 2p., 2nd 2p., 3rd 2p., 4th 2p. 19th 2p, and the 20th 2p., the wind was moderate and of short duration. On the 5th 2p., 7th 2p. and 8th 2p., the wind was local or almost local. On the 12th 2p. the wind was local and of short duration; on the 14th 2p. the wind was moderate, but in contrary directions.

All these cases are doubtful as to whether there should have been tremors or not.

June (6 cases).—On the 3rd, 9p. wind moderate and local—4th 2p. wind moderate and local, 9p. local. On the 16th 6a. and 27th 2p. wind moderate and of short duration. All cases are therefore doubtful.

July (7 cases).—On 1st 9p. there had been tremors during the preceding 12 hours, and there were tremors next morning —10th 9p., wind quite moderate—11th 2p. and 17th 2p., wind moderate and of short duration—18th 2p. wind moderate, but low barometer over Tokio; therefore there ought to have been tremors; 19th 2p., and 9p. wind moderate.

For six cases it is therefore doubtful whether tremors ought

to have occurred, and in one case there ought to have been a baroseismic disturbance.

August (1 case).—This was on the 27th 2p. The wind was generally 2 and 3, and it is doubtful whether tremors ought to have occurred.

September (3 cases).—On the 6th 2p., wind moderate and of short duration—19th 2p., wind moderate and tremors might have occurred—19th 2p., wind quite moderate. Two cases are therefore doubtful and one inexplicable.

October (1 case).—On the 2nd 2p. the wind was moderate and of short duration.

November (8 cases).—On the 13th 2p., 21st 9p., 24th 9p., and 25th 6a., the wind was moderate, on the 26th 2p. the wind was moderate and of short duration. On the 29th at 6a., 2p., and 9p. there ought to have been tremors. These three cases are therefore inexplicable.

The 60 cases where there has been wind and no tremors may therefore be subdivided as follows :—

First 9 cases, in which it seems that the wind was sufficient to have produced tremors, and which are therefore inexplicable unless it is assumed that the tremor recorder was not in good working order or that wind does not produce tremors ; secondly, 51 cases where the wind was only moderate or else of so short duration that there was not sufficient time for the production of tremors. These cases are largely made up of afternoon sea breezes which, although they have a force of 3, only blow for a few hours.

Conclusions respecting the Observations of 1885.

Altogether 945 comparisons have been made between the occurrence of tremors in Tokio and the state of the wind in Central Japan.

1. With no wind and no tremors there are ..... 651 cases.
2. With no wind and tremors there are 51 cases, which may be subdivided into—
   a. Tremors possibly of subterranean origin ..... 26 cases.

b. Tremors accompanying barometrical depressions	8 cases.
c. Tremors which might be due to preceding wind	17 cases.
3. With wind and no tremors there are 60 cases, which may be subdivided into—	
a. Cases where tremors ought to have occurred..	9 cases.
b. Cases where it is doubtful whether tremors ought to have occurred	51 cases.
4. With wind and tremors there are	65 cases.
5. With local wind and no tremors	101 cases.
6. With local wind and tremors	17 cases.
Total	945 cases.

From the above we see that tremors have been recorded 133 times. The obvious explanation for 65 of these cases (50 °/₀) is that they were caused by strong winds which were blowing at the times of observation. 34 cases (17+17) or 25 °/₀ of the remaining cases, *might* be due to winds which had been blowing a few hours previous to the times of observation or to strong local winds. The remaining 34 cases (26+8) or 25 °/₀ may have been of subterranean origin. The 50 °/₀ of tremors which accompanied strong winds are of longer duration and more marked than the remaining cases which are usually of short duration and feeble.

That earth tremors may in great measure be due to wind receives great support from the fact that when there is a calm in Central Japan, it is seldom that tremors are observed. From the 34 certain cases (26 + 8) when tremors, which have usually been slight, have accompanied calms out of 685 observations (651 + 34), we may say that calms have been accompanied by tremors in less than 5 per cent. of the times of observation.

Appendix.

As a test of the accuracy with which the previous analyses had been made, I asked Colonel H. S. Palmer, R.E., to determine from a series of weather maps (January 20th—May 13th 1886) the nature of the tremor records which had been obtained in Tokio, he not being acquainted with these records.

The rules which were to guide him were as follows:—

1.—With a general calm in Central Japan tremors are rarely recorded.

2.—With a wind in Tokio, or with no wind in Tokio but with a wind blowing against the hills which shelter the Tokio plain, there may be tremors.

The result of examining 257 maps were as follows:—

In 35 instances as to whether there had been tremors or no tremors in Tokio it was doubtful. *In 30 of these cases I found that there had been tremors. In 57 cases Colonel Palmer reported that tremors ought to have been recorded. In 54 of these cases* (94 per cent.) *he was absolutely correct, there having been tremors which were very marked. In 3 cases he was wrong.*

In 165 cases when he reported that there were no tremors, I find that he was right 74 times, while in the 91 cases when he was wrong there had been *slight* tremors.

Had I examined the maps myself I should certainly have expected to have found tremors with some of the 91 cases when no tremors were reported.

In 32 instances where tremors were very marked, Colonel Palmer said that in 22 instances they ought to have occurred, in 8 cases their occurence was doubtful, while in two cases tremors ought not to have been observed. These last ten cases, however, occur intercalated with or at the end of tremor storms made up of various groupings of the 22 cases which were reported upon correctly.

The above examination apparently confirms the idea that many earth tremors, and especially those which are well marked, are closely connected with the occurrence of wind.

V.—EARTH TREMORS ON MOUNTAINS.

In September, 1884, in company with Mr. W. Wilson, C.E., and Mr. N. Mano, M.E., I ascended Fujiyama which is

about 12,440 feet in height. Whilst on the top we were unable to undress, wash, or eat anything but the plainest of food. These and other discomforts, amongst which were the difficulties of breathing, prevented our remaining on the mountain for more than five days.

During this time we obtained observations during the day and night extending over a period of three days. These observations were made by observing the position of the end of the pointer of a tromometer as it moved across a scale of millimetres. The instrument was installed on the top of a large block of lava, deeply buried in ashes, in the corner of a stone hut in which we slept. It was covered with a wooden case. Outside of this there was a tent made of oiled paper. The instrument was, therefore, well protected against currents of air. Before commencing readings, the weight was suspended for about fifteen hours by the same wire on which it had hung for many weeks when in Tokio. To test the effects of moisture on the instrument, at the end of the observations I poured a large quantity of water all round the block of lava forming the support. This produced no visible change in the reading of the instrument.

The scale from which the readings were made, and which was immediately below the end of the pointer, was a piece of metal on which there were a series of concentric circles one millimetre apart. A series of straight lines crossing the centre of these circles gave the points of the compass. Had the scale been a series of lines at right angles to each other, the readings would have been more definite. The results of interest connected with these observations are :—

1. That the movements on the top of the mountain were much greater than those which I usually observe in Tokio.

2. The tremors, or slight swing-like movements of the instrument, did not neccessarily accompany the wind.

3. That during heavy south and south-east gales the direction of displacement of the pointer was towards the

south-east, which is the same result as would be obtained if the bed plate of the instrument were raised on the south-east side, or if the mountain had tipped over to the north-west.

My colleague, Mr. T. Alexander, treating Fuji as a conical solid made of brick, with a wind load of 50 lbs. on the square foot, found the slope and deflection of a point 100 feet below the apex of the cone. This calculated slope was two or three times greater than the greatest deflection which I measured.

As it is difficult to imagine that a mountain could suffer deflection by a wind pressure, I will not insist upon the fact that deflection actually occurred. It is however curious that the results of calculation and observation should point in the same direction.

If the observed movements of the pendulum were due to a tip of the mountain, they might equally well have been observed at its base.

The actual observations are given in the following tables :—

1884. Day	Hour	Temperature Fahr.	Barometer	Pendulum	Direction from Starting	Remarks
Aug. 12	10.0 A.M.	50°	19·02	0·50	NW	Almost still
	11.45	50	19·02	0·50	NW	Slow swing from 0 to 1 on NS line
	12.30	51	18·97	1·00	NNW	Still
	1.0 P.M.	51	—	0·00		Now and then a slight motion. Temp. in sun 92° F
	3.0	53	18·97	1·00	SE	Slight swing in NE and N quadrant from 0 to ·5
	4.0	50	18·95	3·00	SE	Slight movement. Strong wind W to S
	6.0	48	18·95	4·00	SE	ditto. ditto. ditto.
	7.30	46	18·95	4·20	SE	Slight movement. Outside temp. 6° C.= 42° F
	9.0	46	18·90	3·00	SE	Slight movement. Strong S wind
	10.0	46	18·95	3·00	SE	Very slight motion. Strong S gale
Aug. 13	0.45 A.M.	46	18·95	2·00	SE	Slight motion. Strong S gale
	4.30	42	18·92	1·50	SSE	Slight motion. Swings from 1 to 2·5 SE to S. Strong gale
	8.0	45	19·92	2·50	SE	Swing 2 to 3 N and S. South wind. Gale abating
	9.30	45	18·92	1·50		Swing 1 to 2 in the E aud NE quadrant. Mist and rain. S wind
	10.30	45	18·90	1·50		ditto. ditto. ditto.
	12.0	45	18·90	1·50		Slight swing in E and NE quadrant. Still Strong S wind and rain
	1.30 P.M.	46	18·87	1·00		Slight swing in E. and NE quadrant. Strong SE wind and rain
	2.45	47	18·87	1·50		Slght swing now and then, ·5. Strong SE wind and rain
	4.45	48	18·87	2·00		Swings 1·5 to 2·5. Barometer pulsating ·01 in. Wind abating, rain continues
	7.0	50	18·91	1·50		Slight swing 1 to 2 E and W. No wind. Mist
	9.0	46	18·95	2·25		Swing 2 to 2·5 on E line. Slight W wind. No rain
Aug. 14	0.15 A.M.	46	18·95	2·50		Swing 2 to 3 on E and SE quadrant. Fine night. Moon up
	3.0	44	18·96	2·00		Swing on division 2 NE and SW. In SE quadrant
	6.0	43	18·96	2·50		Swing on SE l ne, 5
	7.30	45	19·00	3·50		Swing on E and SE quadrant between 3 and 4, SE and NW
	11.30	46	18·99	4·50		Swing on E and SE quadrant, now and then swings to 5. Position of pointer ESE
	1.0 P.M.	48	18·97	5·50		Swing motion in ESE quadrant.
	2.10	46	19·00	6·00		Slight EW motion in ESE quadrant
	3.0	48	18·99	6·00		ditto. ditto. ditto.
	4.0	47	19·01	6·25		Slight EW motion in ESE quadrant. Slight W wind
	5.0	47	18·98	6·25		ditto. ditto. ditto.
	6.0	46	18·98	6·25		Slight NE SW motion in ESE quadrant
	7.0	46	18·95	6·00		Slight NE SW motion in ESE quadrant. Wind dropping
	8.0	46	19·00	5.00		Slight motion ESE quadrant. W wind rising
	9.30	45	19·00	5·00		Slight motion ESE quadrant. Wind dropping
	11.30	44	18·95	5·00		Swing 4·5 to 5·5 in ESE quadrant. W wind strong
Aau. 15	1.0 A.M.	42	18·90	5·25		Swing 5 to 5·5. Strong W wind and fog
	3.45	42	18.93	4·50		Swing 4 to 5. Strong W wind and fog
	7.0	44	18·90	4·00		Nearly still. Strong SW wind and fog
	8.0	44	18·94	4·00		Slight movement. Wind dropped. Heavy fog
	9.0	44	18·94	4·00		In ESE quadrant still. S wind gentle

After this last observation a quantity of water was poured round the foundation, and during the next hour several observations were made, but no change in reading could be detected.

All the thermometer readings are about 1·5° too high, and the barometer readings ·068 too high. Although none of the temperature readings indicate freezing, water in the doorway of the hut was several times thinly covered with ice. Under the boards on which we slept there was a thick bed of ice, and in the adjoining crater, about 600 feet deep, there were large beds of snow.

VI.—GENERAL CONCLUSIONS.

The relationship which the occurrence of tremors has to the lunar and solar motions and the seasons have already been detailed in a previous paper on Earth Tremors published in the Transactions of the Seismological Society, Vol. VII. Part I.

The chief object of the present paper has been to show the relationship which earth tremors hold to barometrical fluctuations, barometrical gradients, and the wind. The analyses which have been made show the following results :—

1.—Earth tremors are more frequent with a low barometer than with a high barometer, but even with a low barometer it may often happen that tremors are not observed.

2.—With a high gradient tremors are almost always observed, but when the gradient is small it is seldom that tremors are visible.

3.—The stronger the wind the more likely is it that tremors should be observed.

4.—When there has been a strong wind and no tremors such wind has very often been local or blowing inland from the Pacific Ocean. We must not overlook the fact that such winds are sometimes accompanied by tremors. Winds of short duration are seldom accompanied by tremors.

5.—When there has been little or no wind in Tokio and yet

tremors have been observed, in most cases there has been a strong wind in other parts of Central Japan. In the case of winds working up Japan from the S.W. this has been very marked, tremors being felt in Tokio several hours before the arrival of the wind.

When neither wind nor tremors are to be observed in Tokio there is usually a general calm in Central Japan.

6.—From the observations in 1886 p. 58 we see that there were 10 days out of 45 when there were tremors which could not be accounted for by winds blowing at a distance, and on p. 61 that there were 3 days out of 20 when there were winds which ought to have been accompanied by tremors, while tremors were not observed. By combining these observations we may say that about 80 per cent. of the tremors observed in Tokio may be accounted for as the result of distant or local winds.

From the observations made in 1885 it seems that 50 per cent. of the tremors certainly accompanied strong winds while 25 per cent. of the remaining tremors *might* have been due to wind. The remaining 25 per cent. of the tremors observed may have been of subterranean origin. These tremors were of *short duration and feeble*. Out of 685 observations when it was calm in Central Japan *slight* tremors were only observed 34 times, that is in less than 5 per cent. of the number of times of observation.

7.—The earthquakes which have been recorded do not appear to be connected with earth tremors more than that each are more frequent at the same seasons.

8.—Earth tremors are as severe upon the summit of a lofty mountain as they are in the plains.

That tremors may be produced in a district across which a strong wind is blowing causing trees and buildings to vibrate is a phenomenon about which there can be but little doubt. The more important question, however, is whether a strong wind blowing against a heavy range of mountains such as sur-

rounds the Tokio plain upon its western and northern sides can produce tremors which will be transmitted any distance upon their leeward side? If we stamp upon moderably hard ground it is easy to see the resulting tremors in a dish of mercury at the distance of 100 feet. By gently rocking a heavy piece of timber one foot square and three feet high, the resulting tremors may be seen at a distance of more than 150 feet. Farther, by watching an image reflected in a small quantity of mercury by means of a theodolite it appears that there is an appreciable time after the commencement of the rocking before the movement in the mercury attains a maximum. This experiment was a crude one, but it apparently indicates that the distance to which tremors of a given magnitude may spread will partly depend upon the length of time the force producing them is in operation. We have something very similar to this in the case of the ripples, the choppy sea, and then the larger waves which outrace a severe storm upon the ocean. On the coast of Iterup in 1881, I was witness of such a phenomenon. On a bright sunshiny morning I saw a black line of ripples advancing across the surface of a smooth sea. These were followed by short waves. Some hours afterwards these grew into larger waves, which were subsequently followed by the wind which in the first place acting at a distance had evidently been the cause of the whole disturbance.

The vibrations produced by a railway train may be observed at a distance of more than a mile. Colonel H. S. Palmer relates that the tremors produced by a crowd of holiday makers in Greenwich Park, have been observed to continue for many hours after the crowd had dispersed (see Trans. Seis. Soc. Vol. III. p. 150). That the summits of high mountains at the time of a storm may be in a state of unusual tremor has been proved by actual observation. That wind pressure may possibly cause deflection in a mountain has been shown both from calculation and observation. With these facts before us it seems probable that a strong wind blowing

against a high range of mountains could not fail but produce tremors which may be propagated to a considerable distance upon their leeward side. That tremors have accompanied such conditions is an observed fact.

Among the facts which are contrary to these views are the observations that tremors sometimes occur when there are neither local winds nor winds which are blowing within a distance of 200 or 300 miles, and also that tremors may be observed at a considerable distance beneath the surface. Prof. Rossi observed tremors in the Grotto di Roca de Papa 18 meters under the soil. It may possibly be argued that tremors produced on the surface may be transmitted to a distance beneath the crust of the earth.

In conclusion, so far as my observations have hitherto gone in Japan, *it appears that the majority of earth tremors are movements produced by the action of the wind upon the surface of the earth and that these may often be propagated to distant places where wind disturbances have not occurred.*