ABSTRACT OF A REPORT TO THE BRITISH ASSOCIATION.

By John Milne.

Investigation of the Earthquake and Volcanic Phenomena of Japan. Thirteenth Report of the Committee, consisting of the Rt. Hon. Lord Kelvin, Professor W. G. Adams, Mr. J. T. Bottomley, Professor A. H. Green, Professor C. G. Knott, and Professor John Milne (Secretary). (Drawn up by the Secretary.)

On the Movements of Horizontal Pendulums.

In a report to this Association in 1881 reference was made to the observation of earth-tremors which it was thought might be connected with the occurrence of earthquakes. The analysis of records obtained during succeeding years showed that the surmise was without foundation. In 1883 an account was given of experiments with various forms of tromometers and delicate levels. The Report for 1884 contained further notes on the observations of earth-pulsations and earth-tilting. In 1885 an instrument was described which gave a continuous record of tremors and deflections of the vertical, and reference was made to earth-waves which had a period of from fifteen to sixty minutes. The Reports for 1887 and 1888 formulated certain laws respecting the occurrence of earth tremors or pulsations. Full accounts of all this work have been published in the "Transactions of the Seismological Society." Last year I described to this Association a method for the investigation of earth-pulsations and earth-tilting, which consisted in making a continuous photographic record of the spots of light reflected from mirrors carried by two horizontal pendulums. These pendulums, which swing in planes at right angles to each other, are each made from a piece of aluminium wire, 60 mm. in length, tipped with a needle point resting in an agate cup. This is held in a horizontal position by means of a quartz fibre. When adjusted so that the period of swing is from five to six seconds, I find that a deflection of the spot of light upon the recording film of 1 mm. with one instrument corresponds to a tilting of 0.54″, and the other instrument of 0.68″. The distance of the lamp and film from the mirrors, which are arranged to swing one above the other, is 3 feet

When I described this instrument in 1892 I referred to it as being new. In this I was mistaken, as similar arrangements have been used in Potsdam and other places by Dr. E. von Rebeur-Paschwitz (see "Der. Ksl. Leop.-Carol. Deutschen Akademie der Naturforscher," Band LX. No. 1). In Japan the primary object of the observations was to obtain continuous records of earth-waves (*tremors*), with the result that with these records the records of other phenomena like those of earth-tilting were found. In Potsdam the cycle of observations was reversed, the primary object being to record small changes in the vertical, with the unavoidable result that distant earthquakes, tremors, and other phenomena were also recorded.

The pendulums I have used have been exceedingly light, and intended to follow the movements impressed upon them by a succession of earth waves.

The pendulums of Dr. von Rebeur-Paschwitz were comparatively heavy, and were adjusted to move with periods of from twelve to eighteen seconds.

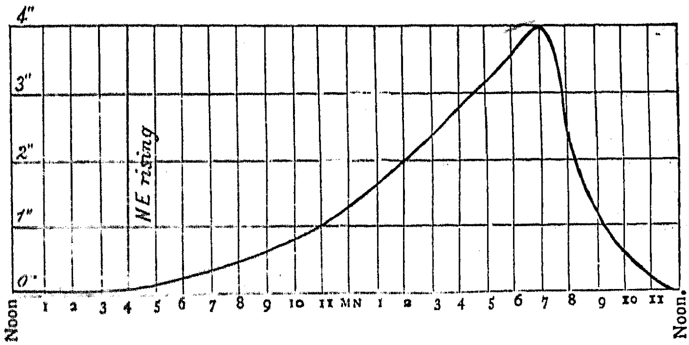
The results obtained in December and January last are described in detail in the *Seismological Journal*, whilst that which has been done between February and April is briefly as follows:—

Daily Tilting.

Almost every day the records show that the spots of light have been displaced in a direction which would correspond with a displacement should the N.E. or N.N.E. side of the column on which the pendulums stand be gently raised, and then gently but rather more quickly lowered. Occasionally the tilting is from the north, the pendulum in the meridian which records the east and west motion remaining stationary.

The movement commences about 7 p.m., and continues steadily up to about 7 or 8 a.m. From this to about 10 a.m. there is a quick return to the normal position, where it remains until evening. The amount of tilting which would produce these deflections is from 2″ to 10″. The average, as shown in the diagram, is about 4″.

FIG. 1.—AVERAGE DAILY N.E.-S.W. TILTING OF A STONE COLUMN IN TOKIO, FEBRUARY AND MARCH, 1893.



The following table is a comparison of the movements observed by Dr. von Rebeur-Paschwitz and those observed in Tokio:—

Movements of Pendulums.	Wilhelmshaven.	Potsdam.	Teneriffe.	Tokio.
Completion of Easterly movement (E. sunk)	2 P.M.	3 30 P.M.	3 to 4 P.M.	7 P.M.
Completion of Westerly movement (E. risen)	4 or 6 A.M.	8 A.M.	9 A.M.	8 A.M.
Amplitude of motion ...	1″·44 to 4″·32	0″·14 to 1″·13	0″·95 to 0″·04	4″ to 10″

EFFECTS OF CHANGES IN TEMPERATURE.

The tests which have been applied to determine the effects produced by a change in temperature have been severe. After closing all doors a stove which stands about 3 feet distant from the S.W. corner of the column has been lighted, and the temperature raised, for example, from 49° F. to 85° F. This took three hours, and during this time the corner of the column became sensibly warm to the hand. All was then allowed to cool. The effect as shown upon the photographic trace and partly by other instruments upon the column was that about half-an-hour after lighting the fire the N.E. side of the column very quickly sank, indicating a tilting from S.W. to N.E. of 2″. After this it sank until an amplitude of 6″ was reached. Here it remained for several hours, and then gradually rose. This, it will be observed, is a result that can be obtained by a change of temperature of 36° F.

Undoubtedly temperature effects exist in the records I have taken; but as it has often happened that the change in temperature during twenty-four hours inside my observatory has not been more than 4° F., while the daily movements have exceeded that which I obtain by a change of 36° F., I cannot attribute the movements I observe to fluctuations in atmospheric temperature in the vicinity of the column.

To determine how far slow and regular changes in temperature may modify the diagrams will be a subject for future investigation.

BAROMETRICAL EFFECTS.

On the soft, marshy ground near Wilhelmshaven, Dr. von Rebeur-Paschwitz observes that a change in the vertical of ¼″ corresponds to a change of 1 mm. in barometrical pressure; in fact, the district behaves as if it were the vacuum chamber of an aneroid. In Tokio the effects are not so pronounced, yet in many instances a N.N.E. tilting has corresponded with a rise in the barometer. On two or three days when the barometrical changes have been small the daily movements have been small, but there are other instances where the daily movement has continued and the barometer has been steady. In the smaller movements, and in the few cases where the direction of one component of the daily movement has been reversed, there does not appear to be any connection with the barometer.

Mr. T. Wada, of the Meteorological Observatory, tells me that the daily maximum and minimum barometrical changes vary with the season, the yearly average being as follows :—

	Minimum.	Maximum.	Minimum.	Maximum.
	h. m.	h. m.	h. m.	h. m.
For North Japan.	3 8 a.m.	*9 0* a.m.	*2 5* p.m.	9 9 p.m.
For South Japan.	3 7 a.m.	*9 2* a.m.	*3 2* p.m.	10 1 p.m.

Those which are italicised are the most pronounced. In winter there are two other periods, viz.:—

	Minimum.	Maximum.
	h. m.	h. m.
For North Japan..................	0 5 a.m.	2 3 a.m.
For South Japan..................	0 5 a.m.	1 7 a.m.

I have not observed any change accompanying the periods.

Possible Relationship with Magnetic Movements.

The relationship between the movements of the pendulums and the daily changes in magnetic declination suggests the idea that the phenomena which are being observed are not altogether unconnected with magnetic influences.

In Tokio the declination is farthest west about 2 p.m., and farthest east at 8 a.m.; that is to say, when the magnetic needle is farthest east the north end of a north-south boom of my instrument is farthest west. That the movements of the horizontal pendulums and those of a magnetic needle take place at the same time but in opposite directions has also been observed by Dr. von Rebeur-Paschwitz in Potsdam and Wilhelmshaven. In my instrument the pivot, which is a steel needle point 8 mm. in length, is pivoted at its southern end.

Geological Structure and Direction of Movements.

A very significant fact, possibly connecting the observed movements with geological structure, is that the N.E. or N.N.E. direction of tilting is at right angles to a well-defined axis of rock crumpling, which shows itself in the N.W. to S.E. strike of the mountains some thirty miles distant, and which line of folding probably continues beneath the plain of Tokio.

Another point not to be overlooked is that the direction of earthquake motion across the Tokio plain is in the majority of cases also at right angles to the direction of mountain strike. During the next summer I shall endeavour to install horizontal pendulums on the rocks themselves, one of them parallel to the dip and the other at right angles to this direction.

Irregular Movements.

It often happens that superimposed upon the daily wave there are sinuosities with amplitudes of 1″ or 2″. These appear to be chiefly marked on the east and west components of the diagrams. They have periods of from three to six hours, and generally occur as a sinking during the early morning or between midnight and 8 or 9 a.m., at which time the east is usually rising.

On February 17, and March 24 and 26, small earthquakes occurred with these sinkings, after which the normal rise was continued. Other earthquakes, which, however, were too small to be measured by ordinary seismographs, were not accompanied by such changes. Before the earthquake of March 6, which probably was of local origin, the spots of light had moved off the scale as if by an abnormally large sinking on the N.E. side. This was at 8.45 p.m. on March 5. I therefore do not know what happened immediately before the shaking, which took place at 8.52 a.m. next morning.

Earth-waves or Earth-pulsations.
(Tremors or Microseismic Disturbances.)

On February 17, 18, and 19 there was a large and wellmarked storm of tremors. The barometer did not fall to any remarkable extent, the lowest I noted being 29.7in. While the movements were continuing the east side of the column was depressed about 2″, and the daily wave did not show itself. With other tremor-storms, which were, however, smaller, the daily wave has been unaffected.

EARTHQUAKES.

From the list of earthquakes at the commencement of this report it will be seen that during the months of February and March nine earthquakes were recorded at the Central Observatory in Tokio. Five of these were measurable by seismographs. Seven out of the nine were recorded at the University Laboratory, which is about 1½ mile distant from the central station. Owing to certain of these having occurred when there had been a temporary interruption in the taking of records—as, for example, when changing a film—it is only possible that three of the seven disturbances should have been photographically recorded.

These records are remarkable for their smallness, apparently showing that, although there had been a sensible motion of the ground, the mirrors had either remained practically at rest, or else they had not been moving for a sufficiently long period of time to produce an impression on the film. As the films, which were prepared for me by Professor W. K. Burton, are particularly sensitive, I am inclined to the opinion that there was less tilting accompanying these earthquakes than there is in the waves which constitute a tremor-storm; in fact, the earthquakes which only produced deflections of 2 mm. were elastic tremors, while so-called tremors which may produce deflections of 25 mm. are earth-waves.

These observations led me to note the effects produced upon a film when the mirrors had been caused to swing by placing my finger upon the iron bed plate which acts as their support. The result was that either a band about 12 mm. in length was produced or else the trace was blurred, and at the blurr a permanent deflection of about 3 mm. was recorded.

As a result of these experiments I conclude that in all cases where lines are invariably opposite to each other in both components, and are seen as transverse markings in the traces, such lines indicate that the mirrors have been swinging, and the question arises, whether these are due to undulations from distant earthquakes or whether they are due to undulations which, if they were continuous, would constitute a tremor-storm.

If they are tiltings due to distant earthquakes, then on several occasions as many as fourteen of these disturbances have been noted in twenty-fours hours. On other days the normal lines are unbroken.

Comparing the photographic traces with the list of 101 earthquakes which were felt in Japan during the month of February, it is seen that only the large ones, like numbers 54 and 61, have been recorded on the film. The traces, however, show that there have been many large disturbances which do not coincide in time with earthquakes noted on the list. It is possible that these may coincide with disturbances which had their origin in other countries, or, what is more likely, with disturbances originating beneath the bed of the Pacific, where, from what we know, seismic activity is at least as great as it is upon the land. An alternative suggestion is that they are the result of movements similar in character to those which constitute a tremor-storm; but whether these are to be attributed to sudden but gentle bendings of rocky strata, or whether their origin is to be sought for amongst causes which are more complex, is for the present a subject about which we are hardly justified in attempting to formulate an hypothesis.

Dr. E. von Rebeur-Paschwitz in Germany has observed fourteen earthquakes—if all of these really are earthquakes—in eleven months. One of them corresponds in time to the great disturbance of October 28, 1891, when Central Japan was devastated.

POSSIBLE CONNECTION BETWEEN THESE OBSERVATIONS AND OTHER PHENOMENA.

Assuming that with appliances similar to those used by Dr. von Rebeur Paschwitz, or to those used in Japan, records of distant earthquakes may be noted, then it would be possible in England, or any other country, not only to note unfelt local disturbances, but also to record, at least, very many of the large disturbances which occur throughout the world.

The importance of such records in determining the velocity with which earth-waves are propagated, or, as was suggested by Lord Kelvin, the determination of elastic constants for the earth's crust, and in solving other problems, is apparent.

Already the observations on earth-tilting seem to have gone sufficiently far to demand serious attention from practical astronomers. There are many reasons for believing that earth pulsations or undulations have a connection with the escape of fire-damp, and they do not appear to be wholly unconnected with the behaviour of certain physical instruments. For example, as the result of a long series of observations made with an Oertling and a Bunge balance, it seems that there are times when it would be impossible to carry out any delicate weighing operations.

The more important results obtained from the observation of these balances were as follows:—

1. The Oertling, which was a light assay balance, moved more than the Bunge.

2. It was seldom that either of the balances was absolutely at rest.

3. During a day the pointer of the Oertling usually crept through half a division of the ivory scale.

4. Although when caused to swing the period of the Oertling was 41 seconds, it would sometimes be found performing complete swings with periods varying between 17 and 60 seconds. Slower motions might take 50 minutes.

5. It was often observed that both balances would start from rest simultaneously and in the same direction.

6. Periods of distubance usually occurred with tromometric disturbances, but both balances have often been moving when tremors were not observable, when the weather was calm and the barometer high, while they have been absolutely at rest during a heavy gale and the barometer at 29.2 inches.

7. The oscillations are not always about the same zero, and the zero for the pointer sometimes changes within a few minutes.

A detailed account of the above observations is given in the *Seismological Journal*, vol. i.

THE EARTH-WAVES OF EARTHQUAKES.

From the observations of many who have experienced a large earthquake we may be certain that at such times the surfaces of alluvial plains have been thrown into a series of undulations. During these disturbances, from observations on the behaviour of fluids in vessels, the water in ponds, the irregular and erratic swinging of seismographs, and the character of the resulting records, it is also clear that undulatory wave-like motions have taken place.

On the occasion of the great earthquake of October 28, 1891, knowing that bracket and conical pendulum seismographs had been tilted, in the Twelfth Report to the Association calculations were given of the maximum slopes of the earth-waves which had caused these movements. Although these calculations may have been interesting on account of their novelty, because any arrangement like a heavy horizontal pendulum when quickly tilted is likely to overswing the point corresponding to that which it would take if the movement had been very slow, serious objections may be raised to the accuracy of the results which were obtained. This consideration led me to devise an angle-measurer in which errors of this description are not likely to occur. It consists of a balance-beam, each arm of which carries a heavy weight so adjusted that the system has but feeble stability. When the stand carrying this is tilted in the plane of the arm, the arm remains horizontal, while a vertical pointer projecting downwards, as in an ordinary balance, is relatively deflected through an angle corresponding to the tilt. This pointer moves a horizontal lever, at the outer extremity of which a sliding needle writes its record on a smoked glass plate. Two such pieces of apparatus at right angles to each other, writing on the same surface, constitute a complete instrument.

In one apparatus the balance-arm with its weights is replaced by a heavy metal disc, supported in a vertical plane by knife edges at its centre.

Already one or two earthquakes have been recorded, and as these are the first written records of earth-waves, a portion of one of them is here reproduced :—

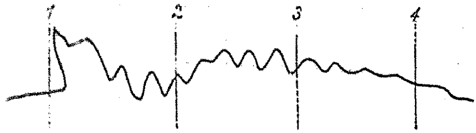


Fig. 2.

It shows the E. and W. tilting during a small portion of an earthquake which occurred at 5.40 p.m. on January 8, 1893. The numbers indicate successive seconds, from which we see that the period of the waves varied from $\frac{1}{8}$ to $\frac{1}{4}$ second. The average angular deflection was about 2′ 40″, and the smallest about 1′ 30″.

The movement continued over at least 20 seconds, dying out with hardly perceptible waves having periods of about $\frac{1}{4}$ second. The N. and S. component of tilting was exceedingly small. The direction in which the waves were propagated was approximately E.N.E. to W.S.W.

Inasmuch as tilting apparently occurs whenever we have vertical motion, an unpleasant conclusion—which, however, is not expressed for the first time—is that all the records hitherto published in Japan where vertical motion has been recorded are of but little value. Not only may the horizontal motion have been exaggerated, but the records of vertical motion have also suffered distortion, this being greatest when the arm of the lever seismograph has been paralled to the direction of the wave-slope. The disturbances in which the vertical component has been marked form about 10 per cent. of what should be our most important records.

What we require to know, for example, as an assistance in investigations relating to construction is the configuration, dimension, and rapidity of recurrence of these earth-waves.

The varying slope of the waves, their period, and their direction of advance, may be measured by the apparatus described.

As an attempt to measure the vertical component of these waves, four lever seismographs have been arranged with their arms at 45° to each other, it being assumed that the record from the instrument with its arm most nearly at right angles to the direction of the advancing wave will be the one which will most closely measure the vertical motion.

Another possible method of measuring this element of earthquake motion would be to avoid errors consequent on tilting by arranging a vertical lever seismograph on gimbals.

Gyroscopes as adjuncts to the solution of these problems have not hitherto proved themselves successful.

On the assumption that the earth-waves in alluvium were harmonic in character and symmetrical in form, in the Report for 1892 it was shown that they might be 20 feet in length; and, knowing their length and period, the velocity of propagation was determined. Even should these waves have lengths several times that amount, some knowledge of their form might be obtained by simultaneously measuring the difference in movement between, say, the heads of a line of stakes at right angles to the direction of the advancing waves and different points of a wire or rod paralled to such a line, but only held in position at its two extremities.

I am led to mention these latter experiments as indications of the important problems which seismologists have yet before them.

LIST OF EARTHQUAKES RECORDED IN JAPAN IN FEBRUARY, 1893.

The list of earthquakes appended to this section of the Report is given as an example of a catalogue which might be compiled from the material which since 1885 has been accumulating at the Central Meteorological Observatory in Tokio.

The approximate centre of a disturbance is indicated by its latitude and longitude, while the energy of the disturbance may approximately be deduced from the figures which show in geographical miles the diameter of the area shaken.

Hitherto investigations respecting seismic activity, the periodicity of earthquakes, &c., have been based upon catalogues where only the *number* of shocks have been recorded, and where the disturbances of one seismic area have been inextricably mixed with those from another.

With a catalogue like the one suggested it would be possible to investigate the rate at which seismic activity is decreasing or increasing either in a given area or in Japan as a whole, giving values to the shocks proportional to the area they had shaken. It would assist us in determining whether there is any relationship between the frequency of earthquakes in neighbouring areas. Inasmuch as many earthquakes seem to be the result of sudden fractures or yieldings taking place during the process of rock-crumpling, it does not seem unlikely that the relief of strain along one axis should be altogether without effect upon neighbouring axes where folding may also be in operation. One interesting investigation of the records of a district which has very kindly been made by Mr. F. Omori has been to plot the shocks which succeeded the great disturbance of 1891 as a curve, the co-ordinates of which are equal intervals of time and the number of shocks occurring during these intervals.

It will be remembered that the immediate cause of the disturbance was the formation of a large fault which can be traced some forty or fifty miles, together with several minor faults. During the seven months which followed the great shock no less than 3,000 shocks were recorded. How many have been recorded up to date has not been calculated, but from the appended list for the month of February, that is sixteen months after the first shock, sixty-two disturbances were noted.

The curve representing this decrease in activity closely approximates to a rectangular hyperbola, which now, with an average of two shocks per day, is becoming asymptotic.

With the law of decrease deduced from these records Mr. Omori calculates that it will take about thirty years for the district to regain its original stability. The records for the Kumamoto earthquake, which took place in July, 1889, show a like result, but with a rate of decrease directly proportional to the intensity of, or the area shaken by, the primary disturbance.

One curious fact connected with the extinction of the Nagoya earthquake is that the district of greatest visible faulting, where valleys were compressed and mountains were lowered, seems to have reached a fair state of quiescence, while the most active settlement, or the district where an extension of faulting is now taking place, is at the S.E. extremity of the main line of original disturbance—a few miles N.E. from Nagoya in Niwa-gun (N. lat. 35° 20′, and E. 136° 50′).

Not only would the publication of the catalogue here indicated furnish material very much better than that which has been hitherto attainable for the continuation of investigations like those made by Perrey, Mallet, and other seismologists, but we should have materials for investigations which would be entirely new.

No.	Day.	Time.	Position of centre. Latitude N.	Position of centre. Longitude E.	Diameter of area shaken in nautical miles.	Remarks.
		h. m.				
1	1	2 42 a.m.	35·20	137·0	5	N. of Nagoya.
2	1	6 43 a.m.	35·40	137·0	3	N. of Nagoya.
3	1	2 45 p.m.	35·5	137·0	3	S. of Nagoya.
4	1	7 21 p.m.	35·30	137·10	3	N.E. of Nagoya.
5	2	10 3 a.m.	35·30	137·10	3	N.E. of Nagoya.
6	2	11 42 p.m.	34·40	132·30	70	S.W. Nippon, Akiken.
7	3	11 30 a.m.	34·50	132·25	3	S.W. Nippon, Akiken.
8	3	5 20 p.m.	35·20	136·50	20	N. of Nagoya.
9	3	7 23 p.m.	34·50	132·30	3	N. of Ise.
10	3	8 34 p.m.	35·20	137·0	3	N. of Nagoya.
11	3	9 30 p.m.	35·20	137·0	3	N. of Nagoya.
12	3	?	34·0	132·10	3	S.W. Nippon.
13	4	4 55 p.m.	35·20	136·10	3	W. of Gifu.
14	5	10 34 p.m.	36·45	138·0	3	Central Nippon.
15	6	1 15 a.m.	35·0	132·50	3	S.W. Nippon.
16	6	7 55 p.m.	35·0	132·50	3	S.W. Nippon.
17	6	9 18 p.m.	36·25	140·0	30	N. of Tokyo.
18	6	9 57 p.m.	35·0	132·50	3	S.W. Nippon.
19	7	2 9 p.m.	35·10	136·50	40	Nagoya.
20	7	9 52 p.m.	35·20	136·50	20	N. of Nagoya.
21	8	3 13 a.m.	35·20	137·0	10	N. of Nagoya.
22	8	4 54 a.m.	43·20	145·30	3	N.E. Yezo, Nemuro.
23	8	5 40 a.m.	35.30	137·0	20	N.W. Nagoya.
24	8	10 10 a.m.	35·10	136·50	10	S.W. Nagoya.
25	8	5 24 p.m.	34·20	133·50	3	N. Shikoku.
26	8	10 0 p.m.	35·30	137·20	3	N.W. Nagoya.
27	9	1 15 a.m.	35·20	136·50	40	N. of Nagoya.
28	9	1 37 a.m.	35·20	136·50	3	N. of Nagoya.
29	9	5 20 a.m.	37·25	138·50	3	Central Nippon, Echigo.
30	9	1 0 p.m.	35·10	136·50	3	Nagoya.
31	10	0 30 a.m.	35·20	136·40	10	N. of Nagoya.
32	10	8 53 a.m.	35·20	136·40	10	N. of Nagoya.
33	11	6 48 a.m.	36·20	140·30	20	N.W. of Tokyo.
34	11	8 40 a.m.	36·10	137·20	3	Fukui Ken.
35	11	9 20 a.m.	35·20	137·0	3	N. of Nagoya.
36	11	6 20 p.m.	37·5	137·20	3	Fukui Ken.
37	11	8 42 p.m.	35·30	137·0	3	N. of Nagoya.
38	12	0 20 p.m.	37·5	137·20	0	Fukui Ken.
39	12	?	36·5	138·10	3	Suwo, Central Nippon.
40	12	5 55 p.m.	35·30	137·0	3	N. of Nagoya.
41	13	6 42 a.m.	35·20	136·50	10	N. of Nagoya.
42	13	7 32 a.m.	35·30	137·0	3	N. of Nagoya.
43	13	8 50 a.m.	35·30	137·0	3	N. of Nagoya.
44	14	6 5 a.m.	39·40	141·30	3	N. Nippon Nambu.

No.	Day.	Time.	Position of centre.		Diameter of area shaken in nautical miles.	Remarks.
			Latitude N.	Longitude E.		
		h. m.				
45	14	11 10 a.m.	35·30	137·0	3	N. of Nagoya.
46	14	11 20 p.m.	35·30	136·50	10	N. of Nagoya.
47	15	2 10 a.m.	35·30	136·50	10	N. of Nagoya.
48	15	8 30 a.m.	35·30	136·50	3	N. of Nagoya.
49	15	10 43 a.m.	35·30	137·20	3	N.W. of Nagoya.
50	16	7 43 a.m.	35·30	136·50	3	N. of Nagoya.
51	16	1 0 p.m.	55·30	136·50	3	N. of Nagoya.
52	16	9 10 p.m.	35·30	137·10	15	N.W. of Nagoya.
53	17	5 45 a.m.	35·40	136·50	3	N. of Nagoya.
54	17	7 15 a.m.	35·30	139·30	50	Central Nippon, near Tokyo.
55	17	7 35 a.m.	35·20	137·0	5	N. of Nagoya.
56	17	7 55 a.m.	35·20	137·0	3	N. of Nagoya.
57	17	0 46 p.m.	35·20	137·0	3	N. of Nagoya.
58	18	3 1 a.m.	35·20	139·50	3	N.W. of Nagoya.
59	18	7 56 p.m.	35·50	137·0	3	N. of Nagoya.
60	19	2 1 a.m.	36·20	140·30	3	N.W. of Tokyo.
61	19	1 57 p.m.	35·0	137·30	20	W. of Nagoya.
62	19	3 36 p.m.	34·30	133·50	3	Inland Sea.
63	19	8 26 p.m.	34·50	132·5	3	S.W. Nippon.
64	19	?	35·0	135·0	100	Only felt at three places on a N.W.-S.E. line.
65	19	8 42 p.m.	34·30	133·0	150	S.W. Nippon, Shikoku, to centre of Kiushiu.
66	19	10 1 p.m.	35.50	132·50	3	S.W. Shikoku.
67	19	11 0 p.m.	34·10	132·10	3	S.W. Nippon.
68	19	11 55 p.m.	35·20	137·0	3	N. of Nagoya.
69	20	1 0 a.m.	34·0	132·30	40	S.W. Nippon and W. Shikoku.
70	20	2 8 a.m.	35·20	137·0	3	N. of Nagoya.
71	20	5 2 a.m.	34·20	132·30	3	S. Nippon.
72	20	10 55 p.m.	34·50	133·20	10	S. Nippon.
73	20	8 12 p.m.	33·20	131·30	3	Kiushiu.
74	20	9 30 p.m.	35·50	135·30	3	Wakayama.
75	20	11 0 p.m.	35·20	137·0	3	N. of Nagoya.
76	20	11 0 p.m.	37·20	139·40	3	Central Nippon.
77	21	2 48 a.m.	36·0	138·0	60	Central Nippon, Kofu.
78	21	2 48 a.m.	35·20	137·0	120	Gifu.
79	21	2 52 a.m.	36·30	140·10	3	N. of Tokyo.
80	21	5 33 a.m.	40·0	141·0	160	N. Nippon.
81	21	6 40 p.m.	31·55	131·30	3	W. Kiushiu.
82	21	8 52 p.m.	35·20	137·0	3	N. of Nagoya.
83	21	10 37 p.m.	35·20	137·0	70	N. of Nagoya.
84	22	3 7 a.m.	35·20	137·0	3	N. of Nagoya.
85	22	6 55 a.m.	35·20	137·0	3	N. of Nagoya.
86	22	9 21 p.m.	34·30	132·0	3	S. Nippon.

No.	Day.	Time.	Position of centre.		Diameter of area shaken in nautical miles.	Remarks.
			Latitude N.	Longitude E.		
		h. m.				
87	22	9 47 p.m.	35·20	137·0	3	N. of Nagoya.
88	23	?	37·0	140·40	60	N. and S. on coast, N. of Tokyo.
89	23	8 40 a.m.	35·10	136·50	3	W. of Nagoya.
90	23	5 0 p.m.	35·20	137·0	40	N. of Nagoya.
91	23	8 30 p.m.	35·40	139·50	3	N. Nippon.
92	24	4 50 a.m.	37·20	137·0	3	N. of Nagoya.
93	24	5 14 a.m.	35·20	137·0	3	N. of Nagoya.
94	24	5 0 p.m.	35·20	137·0	3	N. of Nagoya.
95	25	0 40 a.m.	35·30	137·20	3	N. of Nagoya.
96	25	7 38 a.m.	35·30	136·50	10	N. of Nagoya.
97	25	8 20 a.m.	35·30	137·20	3	N. of Nagoya.
98	25	5 14 p.m.	35·20	137·0	3	N. of Nagoya.
99	26	11 20 p.m.	35·20	137·0	3	N. of Nagoya.
100	27	4 50 a.m.	35·20	137·0	3	N. of Nagoya.
101	28	11 56 p.m.	55·20	137·0	3	N. of Nagoya.

NOTE.—The reason that the diameter of the area shaken by many shocks is given as three miles is because the shock was only recorded at one place, and from investigations on areas disturbed by small shocks this number may be taken as approximately correct (see "On a Seismic Survey made in Tokyo," *Trans. Seis. Soc.* vol. X.).

OVERTURNING AND FRACTURING OF MASONRY AND OTHER COLUMNS.

In the Twelfth Report (1892) it was stated that the form of a wall or pier which, rather than snapping at its base, would, when subjected to horizontal reciprocating motion, be as likely to snap at any one horizontal section as at any other, had been determined. (See *Seismological Journal* Vol. 1.)

A brick building with walls approximating to this form has been designed and built by Professor K. Tatsuno on the University compound. Mr. C. A. W. Pownall, M.I.C.E., has constructed brick piers for the bridges on the Usui Pass, some of which are 110 feet high with similar sections. (See Frontispiece.)

An experiment relating to overturning which is in progress is to determine the relationship between the dimensions of a body and the amplitude of motion which will fail to overturn the same, no matter how short the period of motion may be.