ON THE MITIGATION OF EARTHQUAKE EFFECTS AND CERTAIN EXPERIMENTS IN EARTH PHYSICS.

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There seems but little doubt that since the earliest times, all irregular and sudden manifestations of nature's powers, whether by wind, by fire, by water, or by the shaking of the ground, have excited the imagination, given rise to superstitions, and as a result of terror and the terrible effects of great disasters, created a desire to avoid results which might follow their repetition.

As a remarkable illustration of this latter effect, we have the action of the Imperial Government of this country, who being desirous of avoiding a repetition of the disasters following a shaking like that which on October 28th, 1891, devastated the provinces of Mino and Owari, have set aside a sum of 42,000 *yen* to be used as an assistance in making investigations, which while enlarging our knowledge of earthquake phenomena, will make us better able to mitigate their effects.

I do not know the ideas that each member of the Imperial Parliament held when he voted for this expenditure—which, may be supplemented by additional grants in succeeding years—but it is fair to assume that the actuating motive was to avoid, or at least to palliate, the effects of the terrible shakings which from time to time devastate this Empire.

Last year in Central Japan over 4,000 square miles had been tossed into a sea of waves, the country was fissured throughout its length and breadth, forests had slipped like avalanches from mountain sides, valleys had been compressed and the areas of tenements reduced. Allotments of ground had been relatively shifted, whilst engineering structures and buildings throughout the district had been shattered or destroyed.

Official reports tell us that 9,960 people were killed, 19,994 were wounded, 128,750 houses were entirely destroyed, and all other buildings within an area of many thousands of square miles were severely shattered. To sum the matter up, we are well within the mark if we say, that during at least half a minute Japan was suffering a loss at the rate of one million *yen* per second.

There is but little doubt that the picture of this disaster was in the minds of those who acquiesced in the proposal, and that they consider it would be well to prevent, or at least to mitigate, a repetition of such calamities; the nature of the work to be pursued, and the methods to be followed when carrying the same into effect were entrusted to a Committee composed of distinguished engineers, architects, physicists, geologists, and other scientists in this country.

To carry out the task that is now before them in its entirety, is an impossibility. Earthquakes cannot be prevented; and so long as they continue, from time to time buildings must suffer damage. There is, however, not the slightest doubt that by attention to the result of experience in this and other countries, and by taking advantages of the knowledge gained from experiments on earth motion, more particularly those which have been carried out in this country, so much may be done in the modification of various structures that it will practically be an impossibility to have a repetition of a disaster so extensive as that which recently took place in Mino and Owari.

So long as we neglect the results of these experiences and experiments, we may expect—nay we even invite—a repetition of those calamities, and at any moment thousands of lives may again be lost and in a few seconds the country may once more be compelled to meet a forced expenditure of many millions.

Rules, which, if carried iuto effect will most certainly mitigate these natural calamities, have already been formulated in many earthquake countries, and, with the reasons which have led to their adoption, are to be found in Vol. XIV. of the Transactions of the Seismological Society of Japan. To bring these, or their modified form, into force, would no doubt be a proceeding extending over many years.

During this time, certain special investigations, relating to the stability of walls, and the nature of certain hitherto neglected peculiarities in earthquake motion, ought to be made. Further, we might even go so far as to see whether it is not possible to forewarn ourselves against the coming of these dangers. Up to the present all our endeavours to foretell the occurrence of earthquakes have failed, and we are without means of definitely stating when and where an earthquake may be expected. Although the prediction of these fitful workings, from all that has hitherto been done, seems to be almost an impossibility, there yet remain investigations which should be made, before we relinquish what appears to be an impossible task, and in the following summary of what may be done to palliate the effects of earthquakes, one of them is indicated.

1.—Construction.

Some years ago, at the suggestion of His Excellency the late Mori Arinori, a Committee was summoned to consider Construction in Earthquake Countries, and as a contribution to the work, the writer with the cöoperation of his friends, communicated with all earthquake countries in the world, and obtained from them rules and regulations respecting building, which had been enforced with the object of minimizing the effects of earthquakes. These, together with plans, drawings, opinions, the deductions to be drawn from the author's observations in Italy, Manila, and Japan, and also the results of many special experiments bearing upon construction, were embodied and summarized in Vol. XIV of the Transactions of the Seismological Society. These have been criticized by engineers in Japan, and in two papers read before the Institute of Civil Engineers in London, they were commented upon at considerable length by many who had been engaged in construction in South America and other earthquake countries. Taking this work as it now stands, it is the writer's opinion that it contains sufficient material to form a basis for rules with which all buildings of a foreign type erected in the earthquake districts of Japan should comply. It also contains much that may be taken advantage of, in the carrying out of engineering works, as for example in connection with railway work, and very much more that is capable of application in the ordinary Japanese dwellings. To extend the usefulness of the latter, it is necessary for architects and builders in conjunction, to determine how far the principles applied in a foreign earthquake-proof building, can be applied to a Japanese house without altering its form or increasing its cost. Can greater stability be obtained by diagonal bracing, by the introduction of angle iron at joints, without such an extravagant cutting away of material as is at present practiced, and by using a lighter roof, &c.? It is evident that that much can be done, but to accomplish it in a manner tending to minimize the difficulties of its adoption, consultations will have to be held with the ordinary builder, the house carpenter, the blacksmith, and the manufacturers of tiles and other roofing materials, whilst disputed points must be subjected to experiment.

Types of buildings, having in this way been decided upon, models, drawings, and descriptive pamphlets of the same should be issued to all districts where earthquakes are frequent. At important places full-sized buildings which may be utilized for government purposes, schools, and the like, may be erected as required.

This latter course would not only give actual examples of what was required, but it would give local builders an opportunity of fully realizing that which was required by others.

Of next importance come the engineering structures like bridges, dykes, reservoirs, tall chimneys, &c. Up to the present almost everything has been carried out on the lines of European practice, and that this has failed, has been fully testified by the results of the last great earthquake. For example, it is doubtful if a pier to carry a bridge has ever—either in this country or any other—been designed with a view, not only of carrying the superincumbent load, but of resisting more or less horizontally applied stresses due to its own inertia.

A common wall put together with a mixture of lime and water, although perfectly stable, so far as its weight is concerned, is utterly valueless against horizontally applied forces.

Reasoning and experiments show us that these structures should have horizontal sections the strength of which decreases with the height, while the strength and adhesivity of the cementing material ought to approach that of the masonry.

To carry these and other principles into force will require engineers to consider the results of their past experiences, the results of experiment and reasoning, to carry out new investigations, and finally to draw up rules to be followed for construction in the future.

2.—Rules and Regulations.

Taking the material already in our possession, especially that relating to buildings of a foreign type, it seems desirable that a summary of the same should be presented to the Imperial Parliament for their consideration, with the object of subsequent legislation on these matters.

At the present time, in Tokyo and all large cities, buildings of a foreign type are springing up with alarming rapidity, and the more they are allowed to increase, the greater will be the disaster when they fall, and this, many of them will most certainly do on the occurrence of an earthquake of moderate severity.

In connection with these laws, there are several points of importance which have escaped the attention of legislators in other countries; for example: it would be well to specify a definite strength to be given to mortar or cement joints—it would appear to be advisable to make the regulations more rigorous for buildings in dangerous situations, as for example along a river bank, &c.

3.—Experiments to increase our Knowledge of the Nature of Earthquake Motion.

In consequence of work which was carried out in Japan, and in Japan only, we have now absolute measures of earthquake motion as received at any particular point. We know the distance through which a point moves back and forth, and the rapidity with which these motions are performed. These quantities are no longer matters of opinion or deductions from hypotheses, but they are recorded as absolute measures which can be used by the engineer when constructing to withstand the forces they represent. For example: he can say that the results of observation do not show that a building is likely to receive a shock greater than that it would experience if it were placed on a truck which commences to move with a velocity of 10 feet per second, and therefore rather than making a building strong, because an earthquake is strong, he can construct to withstand the effects due to a measurable force. Further, the results of experiments have shown him the form and strength required in different portions of his structure. Again, experiments have shown that the motion 10 or 20 feet below the surface is less than it is on the surface itself. Advantage has been taken of this discovery in the erection of several important buildings in Tokyo, which rise from a basement, instead of, as in ordinary practice, from the surface. In this and other ways, have scientific enquiries respecting earthquake motion resulted in knowledge which has received an immediate practical application. Much more, however, has yet to be learned before we can state with confidence that our knowledge of earthquake motion is approximately perfect.

For example :—it is desirable to know the length of earthquake waves, of which there are at least two kinds, waves which may be compared to those of sound and those which are more like those we observe in water. In neither case have we waves which are altogether truly elastic, or waves which are entirely due to gravity, but we have waves embodying both of these characters, the exact nature of which will vary with the character of the initial disturbance, their proximity to their origin, and with the nature of the medium through which they are propagated.

To measure the former—which, like the latter, probably vary in length as they are propagated through a varying medium—we require more definite knowledge respecting the velocity with which earthquake motion is propagated. The latter, which are noticeable at the time of large earthquakes, and when vertical motion is pronounced, may be measured either in a similar manner, or by specially designed instruments, which give not only the period of their movements but also record their varying slope.

In the latter case, in order to define the dimensions, as well as the form of the passing waves, in addition to the information respecting period and change of form, we need records of the vertical displacement. As ordinary seismographs for vertical motion may be affected by changes in inclination, a special form of seismograph, which will at least give an approximation to the true vertical motion, has been constructed.

As has often been pointed out before, both in discussions and in print, we see that our present seismographs are of but little value as measurers of earthquake motion, whenever a vertical component is strongly defined. At a distance from an origin, near the end of a disturbance when the earth waves are *slow*, and on a plain like that of Tokyo, we have many reasons for believing that they are symmetrical in form. For waves of this type the ordinary bracket seismograph has been used for measuring their angular configuration, and thus approximate dimensions have been calculated.

An instrument more generally useful would probably be a *quick vibrator*, which has small inertia, and, is in its action, *dead-beat*. The records of such an instrument taken on a *quickly moving surface*, would give us information respecting angular configuration; and this, in conjunction with a knowledge of period and vertical displacement, would enable us to define the form and dimensions.[1] We have evidently here a new field for experiment and observation, the results of which will extend our knowledge of the exact character of earthquake motion.

As another example of the problems which are yet unsolved is the determination of the extent to which two neighbouring points of ground accord in their movements. The practical application of information of this character is obvious, for it is evident that if we are assured that a piece of ground carrying a building moves similarly and simultaneously in all its parts, the construction of such a building may be different to one which is being racked by one portion of it moving in one direction whilst another part is moving in another.

Another direction in which seismological investigations may be pushed, is the determination of the relative intensities of earthquake motion as felt at a number of neighbouring stations. Some years ago a fairly accurate seismic survey was made of the compound of the Engineering College at Tora-no-mon, when it was shown that on a piece of ground only a few acres in extent, the motion experienced on one part of it was invariably very much greater than it was on other parts. In other words, the movements were so different on the two sides of the compound, that a building on one side of it might be shattered, whilst a similar building on the opposite side might remain undisturbed. Investigations of this description need amplification.

[1] An instrument designed and put up by the author intended to measure angular displacements, consists of two similar parts placed at right angles—each part being a beam loaded at either end and carried on knife edges at its centre, as in an ordinary balance. The portion corresponding to the pointer of a balance, moves a horizontally placed multiplying lever, one end of which records its motion on a moving smoked plate.

4.—An Extension of the Functions of the Earthquake Bureau now established at the Chuwo Kishodai (Chirikioku).

Since 1882, the Chirikioku has been in correspondence with some 700 observers who are fairly evenly distributed throughout the empire. When any of these observers feel an earthquake, an account of the same, together with such instrumental records as they may have, are forwarded to the Central Observatory. Based on these records, a map is drawn showing the area shaken by each earthquake, and information relating to its direction, intensity, and other things are recorded. At the end of each year a summary of these records is made, and the area of the land shaken per month, the times when earthquakes were most frequent, &c., are given in forms which are usually tabular. The work that is done is good, and it has undoubtedly already yielded results of great importance to the student of earth physics. It is, however, certain that this department desires the means of extending its usefulness, and it is to be regretted that material means to carry on analyses of the rapidly accumulating records, which are without parallel in other parts of the world, are at present wanting. For example: it is desirable in addition to examining the records as a whole, to analyse the records of earthquakes from particular origins separately, to devote particular attention to particularly sensitive areas, which from time to time show themselves, first in one part of the empire and then in another. For example: many months before the occurrence of the great calamity in Mino and Owari, it seems from the records, that small earthquakes were unusually frequent to the north of Gifu. Possibly these may have been minor yieldings in the rocky crust, which heralded the final crash which devasted the surrounding district. By more extended investigation of the material already accumulated, by special investigation in the districts where disturbances suddenly become unusually frequent, and in many other ways, it seems that there might be a useful extension of the present functions of the Chirikioku.

5.—Prediction of Earthquakes and measuring Secular Movements of the Earth's Crust.

If we were able to predict the occurrence of earthquakes, we should at least have the opportunity of partially avoiding their more serious effects.

Earthquake prophets have been numerous, some basing their predictions on peculiar instincts, others on supposed peculiarities in atmospheric conditions, others on calculations respecting the movements of subterranean tides, which, entering cavities and fissures in the weaker lines of the earth's crust cause sudden yieldings.

The predictions having been numerous, as a result of the laws of chance, it has occasionally happened that they have been fulfilled. In the majority of instances they have failed. At one time, many thought that the frequency of the minute movements called earth-tremors, might indicate the coming of an earthquake, much in the same way that the cracking of a bending stick announces the fact that the limits of elasticity are being passed and it is about to break. Careful investigations in Japan, however, have shown that these movements are unconnected with earthquakes, and are more likely to be the results of stresses due to varying barometric pressures exerted over areas of considerable extent.

The only way in which we are likely to be able to predict earthquakes which suggests itself to the writer, is to determine whether they are preceded by or are in any way related to slow changes of level in the earth's crust.

The hypothesis is, that earthquakes are the result of faulting, and that faulting is due to a bending of the earth's crust beyond its limits of elasticity.

The principal reasons for this hypothesis are:—

1. Even in volcanic countries, the majority of the earthquakes which are recorded do not appear to be in any way connected with volcanic action. Before a volcano commences

to erupt, there may be a few slight shakings of the ground, and there is certainly another small disturbance at the time of the final effort, when the rocky material above the crater mouth is burst asunder. These occurrences are, however, rare, whilst earthquakes, many of which are large, are of continual occurrence, and whether a volcano is at rest or in a state of activity, these disturbances do not appear to be in any way affected.

2. Earthquakes are frequent where we have evidence of secular movements of the earth's crust; as for example, of coast elevation, or where mountain formation is possibly still in progress. Along the Eastern Coast of Japan the borings of marine shells in a soft tuff rock give evidence of recent elevation. Near Yokohama, the average rate at which the coast appears to be rising is, perhaps, a quarter of an inch per year. Evidences of secular movements are common in most volcanic districts where earthquakes are frequent. Again, earthquakes occur in non-volcanic districts like Switzerland and the Himalayas where mountains are geologically young, and where it is likely that the crumpling of the earth's crust is yet in progress. The earthquake in Mino and Owari was in a non-volcanic district, and it was accompanied by, and in all probability is the immediate result of the formation of a large fault and many minor ones which are now visible on the surface.

3. After nearly all great disturbances we have a long series of smaller shocks, indicating the formation of minor faults, and a gradual sinking of the disturbed strata to a state of rest. On the faces of cliffs and other places where faults are exposed in section, it is a common observation that large displacements are flanked by many minor displacements. These were probably formed after the formation of the primary fracture, and represent the intermittent settlement of disjointed strata.

Assuming then that the majority of earthquakes are interruptions in the general process of elevation, a water level, if of sufficient length, placed at right angles to an axis of elevation, might possibly show fluctuations which would measure this process.

Assume the level to be made of 1½ inch gas pipe about two *ri* (5 miles) in length, laid like ordinary water pipes but terminated at each end by a vertical standard of glass tubing resting on well constructed masonry foundations, then, if any change in the general slope of the country across which the pipes were laid took place, it would cause the water to fall in the one standard, by an amount equal to the height it would rise in the other. Leakage (which, however, might be compensated for by a supply tank connected with the line) would show itself by an equal amount of fall in each of the standards. Records of the level of the water in the standards relative to their foundations, might from time to time be made by direct observation, or continuously by means of photographic apparatus.

As it might be difficult to instal such an arrangement as is here proposed exactly at right angles to an axis of elevation, two lines of pipes at right angles to each other in any azimuths would be required. One line of water pipes placed parallel to an axis of elevation could not be expected to show any changes.

Among the chief results that might possibly be reached by this experiment, would be the determination whether secular changes of level, in quantities sufficiently well defined and rapidly performed to be measurable by this class of apparatus have an existence, and if they exist whether they are in any way connected with the occurrence of earthquakes.

In addition to these, the observations could hardly fail to throw light upon the tilting of columns carrying astronomical instruments, possible changes in the height of observatories, and other important changes relative to sea level, the rate at which harbours may be shallowing, the existence of earth pulsatons, and other phenomena connected with the earth's crust, which have hitherto been outside the range of measurement.

As a check upon these experiments, at intervals of say a year, the difference in height between the two foundations might be determined by ordinary leveling.

As a guide to determine where elevation is most pronounced, and therefore where investigations respecting secular changes may be best observed, the writer suggests that by means of circulars sent to each town and village on the coast, information could be obtained from the old residents as to whether such changes have been observed, or whether there are traditions respecting alterations in the level of the water relatively to the land.[1]

At certain places, permanent rocks might be marked, as was done by the Swedish Government, and the distance between these marks and the average sea level recorded.

As the latter quantity is subject to considerable fluctuations, we can only hope to determine the existence or non-existence of elevation by this method of observation, after long intervals of time.

The writer has suggested that the *relative* elevation of two or more points may be more quickly determined by observing the difference in the records obtained at the same time from two or more tide gauges situated round the shores of a bay where the rise and fall of the tide is not excessive.

If there is no change taking place between sea level relatively to the land, then these differences between the heights measured at the various stations, which heights are measured relatively to certain bench marks at those stations, should when the tide is in the same phase and there are no distrubances, as for example, due to the piling up of the water by the wind, remain constant. The chief assumption here made is that during similar phases of the tide, the surface of the water has the same configuration. By means of a system of stations in

[1] With the kind assistance of Prof. D. Kikuchi these enquiries are now being made.

nearly a straight line, the configuration of the water surface under varying conditions along that line, might be determined. As an illustration of how the work might be systematically performed we will assume that we have at least these tide-guages, each from 10 to 20 miles apart, installed round the shores of Tokyo Bay. With this installation on a series of consecutive days, we can readily determine the following particulars:—

1. Total rise of water from low water to high water.
2. Whether the tide is increasing or diminishing from day to day.
3. Whether at any point in the vicinity of the mouth of the bay there is no tide.

We can then for one or all of these days determine the height of certain bench marks relative to high or low water (these being convenient phases of the tide) or the height at each of the stations above water level at the same time.

Again, say a year afterwards, let us make similar observations when the tide has the same total rise and is increasing or diminishing as in the previous year. Also it will be necessary to determine whether the point of no-tide has remained fixed, and if not, re-determine the water configuration. Then the difference of the differences between the indications in this case at the several stations and those of the previous case, will measure the relative rise or fall.

Any difference in the height at any one station is an indication of total rise. It is evident that in order to measure these changes and to determine the axis of the movements it is necessary to make observations at at least three stations.

In reply to the query as to the amount of change we expect to measure, we may say that the evidences of elevation round the Bay of Tokyo are sufficient to lead us to expect changes at least equal to that which, for example, has been determined on the coast of Italy.

For example :—the temple of Serapis, near to Naples, since its construction, which was antecedent to the Christian era,—prior to the close of the fifteenth century was submerged at least 20 feet, since which time it has risen 23 feet; and since the commencement of this century it has again been sinking. The rate of subsidence has been determined at various times, being from ¼ to 1 inch annually.

Movements of this character are not local, and what is more, they are common to many parts of the world, especially in volcanic districts. In the district near to Vesuvius, during periods of volcanic activity, subsidence appears to have been taking place, whilst when the volcanoes were dormant elevation was in progress.

6.—Observations on Faults.

On the faces of the cliffs surounding the Bay of Tokyo, very many well defined faults, having throws of from a few inches up to twenty feet or more, which might be studied.

Although the rocks on either side of these lines of fracture have settled to a state of rest, yet the fact must not be overlooked that they represent lines of weakness, along which, should local disturbances occur, further yielding might possibly take place. For example :—Owing to a process of general elevation, or at the time of a severe shaking, a gradual or sudden movement might occur. If the throws of several faults—selecting for example several which were near to the stations for tide observations—were measured, any alteration in their measurements would indicate local subsidence, which, although, probably showing a connection with earthquakes, must not be confounded with the more general movements extending over considerable areas.

7.—Rigidity of the Earth's Crust.

As has been suggested to the writer by Lord Kelvin, accurate determination of the velocity with which vibrations are propagated through the earth's crust, would lead to a determination of a certain constant often required by physicists engaged in speculation respecting distortion of the earth's crust due to external attractive influence. Already one or two determinations have been made of the rate at which earthquake motion has been propagated between Japan and Europe, but before these can be applied to the determination of elastic constants, it is necessary that they be repeated with greater accuracy. The best observations of this nature are perhaps those which were made at the time of the great Charleston earthquake, when velocities for the propagation of earth waves reached 5,200 meters per second. As an attempt to measure the bending of a mass of rock as it occurs in nature, some years ago the writer endeavoured to determine whether the roof of the workings in the Takashima Colliery, which extend some distance beneath the bed of the Pacific Ocean, was in any manner disturbed by the rising and falling of the tide. Instruments were prepared and forwarded to Nagasaki, but owing to the death of Mr. John Stoddart, who had kindly undertaken to make the necessary observation, nothing was accomplished.

8.—Experiments in Boreholes.

Many years ago a borehole was sunk in the compound of the Kobu-dai-gakko, to the depth of 100 feet, and at depths of 25, 50, 75, and 100 feet respectively, thermo-electric junctions were established, which enabled the temperature at those depths to be measured at any moment. Boreholes, in which earth temperatures have been measured and heat gradients determined, exist in many countries.

In Germany we find seven holes each exceeding 3,000 feet, and one of them at Schladebach, over 5,700 feet in depth. In the oil regions of the United States we have yearly about 1,000 holes, sunk to depths varying between 1,000 and 3,000 feet.

From observations in these holes, mines, tunnels, &c., an average heat gradient has been obtained, and anything that can be done by sinking a deep bore-hole in Japan, is not likely to add to our present knowledge more than what may be of local interest. A heat gradient, which we have no reason to believe is likely to show fluctuations, can be obtained for the rocks beneath a certain locality, and it will not be exactly the same as any other heat gradient.

Geologically and commercially, a deep bore-hole, carried out in Tokyo for example, may lead to results of considerable value.

It will yield information to the Geological Survey, a bad quality of coal, or hot water may be met with. Even if only pure water is obtained, such a result may be of value in a city not yet possessing a proper water supply. We do not, however, see that it is likely to throw new light upon seismic or volcanic observation, the depth to which it may penetrate being so insignificant compared with the depth at which we may expect volcanic or seismic forces to have their origin.

Although but little may be learned respecting the organization of our mammoth by gently puncturing its skin, we must not forget that boreholes have hitherto only been utilized by physicists, as a means for determining heat gradients, and we may ask ourselves the question whether they may not be employed as a means for making other investigations. For example:—Earth currents are studied as phenomena resultant in differences in potential between points on the surface of the earth. With a borehole at our disposal, may we not determine whether these forces have a vertical component?

9.—Variations in Latitude.

For many years it has been suspected, and now it is known, that we are sometimes from 50 to 100 feet nearer to the pole than at other times. For example: at Berlin at the commencement of 1890 the latitude was 52°.30'.17". In the middle of September it had gradually reached 52°.30'.17".56. By February, 1891 it had returned to 52°.30'.17".06 and in June and July of that year it had risen to 52°.30'.17".53.

It is certainly remarkable that the period of maxima increase in latitude in Berlin (which may correspond with a minima in values for latitude in Japan) should coincide with a maxima of earthquake as recorded in Japan, that is in August and September, 1889, and in May and June, 1890. Until further observations are made the writer is, however, inclined to regard these coincidences as accidental.

10.—Observations on Gravity.

When a pendulum is repeatedly swung at a given station, as might be expected, there is not an absolute agreement between the results leading to the calculation of the acceleration due to the force of gravity. A question which presents itself is whether these slight differences are the result of instrumental and personal errors in observation, or whether it is possible to trace them to some more general influence. For example:—It seems probable that when observations are made at the time of a tremor-storm we have earth movements of a pulsatory nature which might either accelerate or retard the swinging of a pendulum. The writer finds that at the times when tromometic disturbances are pronounced, delicate balances are seriously disturbed. To swing a pendulum at an observatory daily for a year, would certainly be an experiment, the result of which would be regarded with interest.

The abnormal results of pendulum observations, made in the vicinity of mountain ranges, have led physicists to speculate as to the nature of the foundation of these ranges. Will observations as to the value of gravity—made for example on the flanks of Asamayama—show us anything respecting the roots of our volcanoes' internal changes which follow or precede great eruptions or seismic disturbances?

11.—Magnetic and Electric Phenomena.

Although Prof. Tanakadate has shown that after the Nagoya-

Gifu earthquake—which was accompanied by a permanent displacement of rocky strata—an exceedingly slight change is observable in the isomagnetic curves, it does not seem likely that either magnetic or electric phenomena will be the means of forewarning us of the coming of earthquakes.

No doubt much that is of interest may be accomplished by making special magnetic investigations near great lines of faults, and on the flanks of our volcanoes, and for various reasons we may expect changes in the magnetic elements to be observable before and subsequent to eruptions.

It must be remembered that, although so much has been written to show that there is a connection between magnetic and seismic phenomena, that magnetic instruments established in Tokyo, although they are repeatedly shaken by earthquakes, have never yet shown any change other than that which might be produced mechanically. Similarly, much has been adduced to show a relationship between earthquakes and electrical phenomena like earth currents and sudden changes in the potential of the atmosphere relatively to the earth but although many attempts have been made to observe such phenomona, no definite conclusions have yet been reached. (See Earthquakes in connection with Electric and Magnetic Phenemena: Transactions of the Seismological Society, Vol. XV. p. 163.)