SEISMIC SCIENCE IN JAPAN.

GENTLEMEN :—To-day I have the honour of addressing a society whose main object is to collect and systematise facts which are in any way connected with earthquakes and volcanos. It is intended that the society's chief work shall be to gather together and correlate phenomena which emanate from the interior of the earth; and whereas nearly all the learned societies, of which there are so many in European countries, chiefly study that which is on the exterior of our planet the objects of this society are decidedly peculiar. Where the work of a Seismological Society commences and where it ends, would, like the work of many other scientific societies, be difficult to define. In its narrowest sense it would be confined to the description of shakings which from time to time occur upon the surface of the earth's crust. In its broader signification, in its treatment of the origin of earthquakes and their consequences, we might compare its vast extent to the exaggerated representation of the action of a pebble which, dropped into the ocean, we can conceive as being the cause of more or less effect throughout the world. To the geologist a knowledge of earthquakes and volcanos is of primary importance, whilst to the physicist, the meteorologist, the astronomer, the mathematician, the engineer, and, I might add, the physician, the naturalist, the historian, and the student of national character, the study of these phenomena and their co-ordination with the phenomena of other sciences, affords a field for research from which much has yet to be gathered in.

The task is great, and one of the first problems which come before us is to determine how it is to be accomplished. No doubt the same end may be attained by different methods, but it behoves us always to strive after that which is the best. At the outset it would seem well to obtain first a clear idea of the goal we are endeavouring to reach. Next we might consider the roads it would be necessary to follow to attain it successfully, and finally, we might examine how far previous workers in seismology have advanced along the paths we desire to follow.

Work of this nature might be likened to that before an artist, who is asked to complete a picture which has already been commenced. This being the case, we will now ask ourselves how such an artist would proceed. If we were to watch him I think we should first see him stepping back whilst endeavouring to form a general idea of the sketch which had to be completed. Having formed this idea, he would next proceed to scrutinize the work of those who had preceded him, and carefully consider how it was likely to harmonise with that which was as yet undrawn. Being satisfied on this point he would next examine the details of the parts which had already been completed and see how far these were in unison with each other. Perhaps some of these would be perfect, others would require to be renewed, and others to be improved upon.

If the task imposed upon us is at all similar to this, not only must we lay before ourselves the work which has already been done in Japan, but it will be necessary for us to see how far it is in concord with that which has been done in other countries, and picture to ourselves the general results towards which all such labours aim. The scheme proposed is one of descent from generals to particulars; from a goal to be attained to the consideration of the roads which reach it. It is like an argument from theory down to facts. When a savage discovered that by rubbing two sticks together he could make a fire, or when a blacksmith found that by hammering a piece of steel it became so hot that it enabled him to light his pipe, the results arrived at were not attained by a preconceived theory of heat, but from experience, and here facts led up to theory. Although many important generalizations have been arrived at by methods similar to these, we must remember that many of the greatest triumphs of scientific discovery have been reached by methods which are entirely opposite, and instead of facts leading up to theory, theory has led down to facts. It was by following out the theory of gravitation that Adams and Leverrier discovered Neptune, and by investigation based upon the undulatory theory of light, that Sir William Hamilton discovered conical refraction.

In pursuing the question before us, we might either follow the method of Leverrier and Hamilton, or that of the blacksmith and the savage, and in either case we might attain valuable results. Let us take the former and commencing with the idea of what the picture ought eventually to be, consider the details necessary for its completion.

Now, what is the picture we are required to draw?

Amongst the various objects towards which man aims one of the most laudable is, perhaps, a study of the human race, with a view to discover the various factors which have been at work to bring it to its present condition, and, if possible, to remove the obstacles which bar its future progress.

History tells us of fierce wars, the conquest of provinces, the rise and fall of empires, and generally, of the mutual actions and re-actions of a multitude of nations. In its records we read of a gradual increase in knowledge which has led to dissatisfaction with that not suited to the times, and demands for reformation. How far nature has been instrumental in advancing or retarding this onward march of nations is a theme familiar to us all.

If we wish to investigate this latter division of the scheme which is before us, much may be learnt by a study of those operations which are visibly at work around us. For the remainder, however, we must go to those records which are buried in the rocks or have been sculptured on the hills. By doing this we shall find that in nearly every country, long antecedent to the time of man, vast changes have taken place about which the records of written history tell us little. Climates which now are mild and balmy were once cold and stormy. Continents have risen from the ocean and others have disappeared beneath its waves. Lands, which now are fair with corn fields and softly flowing rivers, were once the scene of violent volcanic activity. What would many of the inhabitants of Britain say if we talked to them of the volcanos of the Hebrides and of Wales, or the inhabitants of Hungary when they heard a discussion about a volcano at Chemnitz? When they looked upon these huge hummocks clothed with verdure they might doubt our words, but yet to those who have studied these formations the statements sound as true as that the sun rose yesterday. All is change, and to understand the conditions which we see around us at the present we must endeavour to trace their evolution from the past. Should we, for instance, wish to know the reason why the people of Japan or England are as we see them now, we shall find ourselves driven back from history to geology and from geology to the evolution of our globe. One great influence which has acted upon the people of almost every soil has been their geographical position, which gives to them their climate, and aids or debars them in their intercourse with others. The climate of a country, however, largely depends upon its configuration, and its configuration often depends to a great extent upon the nature of its rocks. The hard rocks will stand up to form the mountains, or, projecting out to sea become promontories, whilst the softer rocks will form the plains, or be cut back to form the bays. The mountains will influence the rain fall; the soils will depend upon the underlying geological formations. The industries of a district will depend upon its geology: in the mountains we shall find miners and hunters leading a life both hardy and dangerous, whilst in the plains we meet the agriculturist whose existence is one of peaceful monotony. In fact, turn as we will, when studying the physical causes which produce the greatest effect upon the human race we are confronted by conditions dependent upon geological structure.

If this reasoning is correct, and so much in a country depends upon its geological character, let us go one step farther and endeavour to find out what it is that produces the geological character itself. Should we pursue this question in all its details we should here enter upon a chain of reasoning which, in its collective form, embraces all that is known under the term Physiography. As a result of such an examination we should find ourselves face to face with that molecular energy called heat, and this we might regard as potentially the producer of almost all the physical changes which the crust of the earth has undergone since the earliest times. On the one hand there is *sun heat* enabling the rivers and the oceans to wear away the land and pile up sediments. On the other hand there is *earth heat* causing elevations and depressions. By these two forces whole continents with their hills and valleys might be destroyed or formed. Should we wish to push our enquiries still farther we might do so, but our steps would be shrouded in a darkness which would make our path uncertain. Therefore rather than continue towards that region which is called "unknowable" let us pause and ask ourselves into what portion of the picture the outline of which has been indicated are we to insert our gleanings about earthquakes and volcanos.

Earthquakes are to us the evidences of sudden jars or blows which, having been struck upon the earth, cause a vibration to travel through a portion of its mass. During elevations or depressions rocky masses may reach their limit of elasticity, and being fractured give such blows. Volcanos are direct evidences of internal heat, and to those who study Physiography they are most important factors in all considerations connected with the internal condition of our earth.

In fact, earthquakes and volcanos belong to that portion of the world's history which tells us about its internal heat and it is to this heat and its fluctuations that nations owe the conditions under which they now exist.

If we then remember that the written history of a people, their character and their pursuits depend so largely upon the geological and physical features of the land in which they dwell, and that these in turn depend upon subterranean causes, the nature of which is best studied by examining earthquakes and volcanos as our witnesses, we shall see that the section of the world's history which has been taken up by the Seismological Society is sufficiently important to demand the attention of many workers.

Not only are we to regard volcanos and earthquakes as witnesses from which we are to extract information about the earth's internal heat upon which all we see upon the surface of the globe more or less depends, but we may look upon them as most important workers in producing minor changes of a local character. Volcanos have built up mountains and sometimes islands. And there is perhaps no place where these structures could be better studied than the country where we now reside.

To many lands volcanos have given a general aspect to the scenery, and by their sudden outbursts have excited terror and engendered superstition. Earthquakes have acted in a similar manner, and the fear which may be created by a shock of unusual severity is well known to all here present. In early times when these phenomena were ill understood, they seem to have excited the imagination and given rise to superstitious awe. It does not seem unlikely that the mountain worship of many countries may be in part the result of such early superstition. Certainly in this country we notice such worship to exist upon all high volcanic mountains, and in Peru we observe that the days on which the most serious earthquakes have occurred have been set aside as days for religious festivals; and the traveller still finds many of the North American Indians regarding their snow-clad and now extinct volcanos with a superstitious fear, the accounts of the eruptions of which could only have reached them by tradition. Farther, it does not seem unreasonable to suppose that these great phenomena, besides stimulating the imagination to the detriment of the understanding, may also have been active in creating hereditary timidity and thus to have become more or less a cause of mental aberrations like madness and imbecility. In other cases frequent shocks, by repeatedly giving rise to a feeling of insecurity, may perhaps have sown the seeds of recklessness and improvidence, which eventually have become characteristics of the nation.

The effect produced upon the weaker members of a community has recently been evidenced before our eyes, and just as continued fear will work its result upon the individual, so may it produce a general effect upon the inhabitants of a country.

We have now briefly indicated the part which earthquakes and volcanos play in the various changes which go on around us. First, we see them as evidences of the internal conditions of the earth without which all our continents might long ago have been levelled with the ocean. Secondly, we see them as individual agents; the creative causes of islands, of mountains, and of great catastrophes, which latter have produced effects both physical any mental. If this then is the position the phenomena with which the Seismological Society have to deal occupy in the great scheme which we see going on around us, it now only remains to consider how far this portion of the picture which is before us has been filled in, and then set to work so far as we are able and endeavour to complete it.

Up to comparatively recent times we have had in an elaborate and exhaustive series of reports prepared by Mr. Robert Mallet for the British Association, an epitome and masterly coördination of all the facts which have been accumulated, and the results obtained in the department of seismic science since very early times. With the results of these reports which are founded upon varied analyses of over seven thousand recorded earthquakes, no doubt most of us are familiar. When looking at the results which have been arrived at, to use Mr. Mallet's words, we must not be discouraged "that after the vast labour bestowed by so many upon cataloguing earthquakes and discussing the results we find they do not even bring us to the threshold of positive knowledge."

Further on, in the conclusion of the same report, Mr. Mallet says "that a further expenditure of labour on earthquake catalogues of the character hitherto compiled, and alone possible from the data to have been compiled, is now a waste of scientific time and labour." The results which have hitherto been arrived at, so far as can be deduced from the cataloguing of earthquakes, are chiefly negative in their nature, and "the main reward of toil so far is the having cleared away the rubbish," and shown us the roads in seismic science above which the sign "no thoroughfare" is written.

Lest any of us should be sceptical it would be well to remember that the opinions quoted are not those which have been based upon the work of any individual, but upon the works and investigations of some of the wisest heads in Europe.

To give a list of the names of these workers would only be repeating what we know already. Foremost among all these workers we have M. Perrey of Dijon and Robert Mallet each of whom have devoted a lifetime to the study of seismic science. The labours of the former of these workers have been carefully examined and criticised by a special committee of the French Academy of Sciences, whilst the writings of the latter have been laid before the British Association. Amongst the names of other contributors to this science we find those of Humboldt, Arago, Biot, Hopkinson, Schmidt, von Seebach, von Hoff, Falb, Fuchs, von Lasaulx, Credner, Vogt, Volger, Palmieri, Rossi, and many others too numerous to mention. At all times geologists, physicists, mathematicians, and men of science generally, have been attracted to the study of earthquakes; they have thought about them, and they have often written on them. Perhaps the best idea of the extent to which seismology has been studied may be gathered from the fact that Perrey, who himself has published some sixty memoirs on the subject of earthquakes, gave in 1856 a catalogue of one thousand eight hundred and thirty seven different works relating to earthquakes.

My reasons for mentioning how much has been done in seismology is to recall the circumstance that others have been in the field before us, and that before commencing any investigation, or putting forward any project, it behoves us, if we wish to avoid labour which may be fruitless, to make ourselves so far as circumstances permit masters of what has gone before.

If we turn to Vulcanology we shall find that the work which has been going on has been quite equal to that which has been done for the sister science.

What is of greatest interest to us dwelling in Japan is perhaps, the knowledge of what has been done and is, at the present moment, doing immediately around us. At first sight the work which has been accomplished may appear small; nevertheless when examined into we shall find that Japan has already contributed some valuable light to our knowledge of this subject.

Amongst the workers in Geology who have told us about the distribution of modern and old volcanic rocks, we have Mr. B. S. Lyman, who, in his voluminous reports, is leaving us a mine of valuable material from which the workers in Vulcanology may extract most useful and important facts. From these reports, coupled with a sketch map of the geological formations of Japan by Mr. J. G. H. Godfrey, together with my own observations, I made a rough sketch of the distribution of old and new volcanic rocks in the island of Nippon, and by cutting out the areas thus indicated and then weighing them against the remainder of the map, which represented country covered with sedimentary rocks, it would seem that the area of country covered by volcanic rocks is to that covered by sedimentary rocks as 2 : 3. That is to say, for the dweller in Japan, who is interested in the study of volcanic rocks, there is almost the same amount of rock exposed for his examination as there is for the ordinary geologist who confines himself to the rocks which are stratified and the alluvial plains. When we remember that these volcanic rocks build up nearly all the high mountains and to a large extent form the core upon which all the sedimentary rocks have been deposited, we see that the material which is before the members of this society waiting to be examined is almost unlimited.

Many of the rocks, which overlie these old volcanic rocks, are formed of a greyish clay like material which in nearly all cases can be shown to be the result of the decomposition of volcanic ejectamenta. Examples of this rock which is called a tuff, can be seen at Yokohama and rising up to form low hills on either side of the Bay of Yedo. Here it is usually regularly stratified, and has apparently suffered but little alteration since its deposition.

Now and then, as, for instance, in the harbour at Yokosuka, we can discover places where the continuity of the beds has been broken by a fault. As we trace these beds of tuff across the plain we see that as they near the hills they show signs cf having been bent, and in many places they are broken. The extent of these breaks vary from a few inches to many feet. At the Kayanoma (Iwanai) coal-field Mr. Lyman has indicated a fault of about 400 feet of horizontal displacement, the existence of which fault has since been proved by mining. Now what do all these faults mean? When each of these breaks was produced was it announced to the surrounding district by a trembling and shaking of the ground? If it was, then those who have been engaged in mapping the faults which exist in various countries have really been drawing up for our inspection the records of bye-gone earthquakes whose energy has disappeared in molecular forces and heat. By the observation of faults it may perhaps be possible to make important inferences about earthquakes of times long past when the interior of the earth was hotter than it is at present, and was in consequence cooling and contracting more rapidly than it does now, so that possibly the giving way of its crust may have been much more frequent.

If we turn now to the volcanos we shall find that considerable work has been done. Of Japanese writers there are a vast number, and from a collection and a translation of their works much would be learnt. Amongst European writers on the volcanos of Japan we find the names of Messrs. Naumann, Marshall, Drasche, and Rein, and in all the books relating to Japan, like the valuable works of Siebold, Titsingh, and Kæmpfer, references to the volcanos of this country are numerous. Although several volcanos like Fuji and Asama have been described to us from the notes obtained by actual visits to the mountains, there are still a vast number of volcanos waiting similar treatment. In this department there appears to exist in Japan as excellent opportunities for observation as we could hope to obtain in any other portion of the globe. Volcanos can here be studied in all their stages. One year we may go to an island like Oshima and only see a steaming fissure. The next year we may go, and in place of a fissure see a cone. Looking down from the heights above into the crater of this cone we may see the liquid lava welling from side to side, and have before our eyes an exhibition of the more immediate causes which cause volcanic outbursts. In other parts of the country we can see volcanos like Onsen near Nagasaki which, after killing half a hundred thousand people and devastating provinces, are now resting their steaming flanks, as if collecting energy for another outburst. In another place we meet the mountain which is quite extinct and whose crater, with its placid lake, forms a haunt for summer tourists. Other volcanos again are remarkable for their size. This winter, while travelling in Kiushiu with Mr. Woolley of the English consular service I visited the volcano Asosan, which to my astonishment I found was a smoking hill rising from the middle of a crater which was approximately from *ten* to *fifteen* miles in diameter. To look into this crater was like looking into a huge pit, the perpendicular sides of which were from 300 to 1,000 feet in height. Although this central peak was smoking and only a few years ago threw out stones and ashes killing several men who were engaged in collecting sulphur near it, I calculated that there were living inside the crater out of which it rises, from ten to fifteen thousand people. Here we have a crater which does not seem to find its equal, in any that has hitherto been described unless we go to other worlds.

Not only are the volcanos of Japan remarkable for their size but they are equally remarkable for their form ; their beautiful curvatures seem to show us that the shape of a volcano is due to the simple piling of loose material, shot out from a central vent rather than to secondary causes like those arising from subærial denudation. Farther, variations in these forms may perhaps indicate to us variations in the size and shape of an internal core, and it yet remains for us after having measured the external slopes of a mountain like Fujiyama to calculate the shape of the internal stony column which would be necessary to support it.

From volcanos I will now pass on to earthquakes which offer to us a field of inquiry which is almost unlimited. In nearly all the books which relate to Japan its earthquakes have in a general way been referred to. How far they have been thought about by the Japanese themselves is evidenced by the vast amount of literature which has been produced upon this subject, and more especially, perhaps, by the existence of earthquake calendars in the publication of which the people of Japan appear to have far outstripped the dwellers of all Western countries.

Lists of the names of many of these books and calendars have been given by Dr. Naumann and Mr. Hattori in papers they have written upon the earthquakes of Japan. Amongst others who have written specially upon this subject I may mention Messrs. Knipping and Chaplin. To endeavour to give an epitome of the results which have been arrived at by each of these writers, might not only be invidious but by its necessary brevity be an injustice to great labour. Therefore, rather than speak of them in detail, I will only refer in general terms to some of the more prominent portions of their investigations.

Ever since Seismology has been studied one of the chief aims of its students has been to discover some means which would enable them to foretell the coming of an earthquake, and the attempts which have been made by workers in this country to correlate these occurrences with other well marked phenomena may, I think, be regarded as attempts in this direction.

Ability to herald the approach of these calamities would unquestionably be an inestimable boon to all who dwell in earthquake shaken countries, and the attempts which have been made both here and in other places are extremely laudable. In almost all countries where earthquakes are of common occurrence these movements of the earth have been more or less connected with certain phenomena which, in the popular mind, are supposed to be associated with the approach of an earthquake. To give a full enumeration of these phenomena, many of which have reference to the state of the weather or the seasons, would be to prepare a table of great length. Even in Tokio I have met with foreigners who will tell you that by a certain oppressive feeling, or by a sultry state of the weather, they have an instinctive feeling that an earthquake is at hand. When we remember that there are sometimes a dozen earthquakes in the month, if prognostications of this description never proved themselves correct we should have, I think, a defiance of the laws of chance.

To decide a question of this description in the minds of all, accurate records of these prophecies would need to be collected for a sufficiently long period of time for comparison with the records of an observatory. That the lower animals are affected by a shock, sometimes even a short interval of time before it actually become sensible to men is a fact almost beyond doubt. Many who are now present have heard pheasants scream a few seconds before we felt a shock as if they had perceived approaching tremors to which we had been insensible. That such tremors do sometimes precede a shock we may infer from the gradual manner in which shakings sometimes have a commencement, and also from the fact that in certain houses where the window sashes or slides are loosely fitted a rattling will be sometimes heard a few seconds before a shock is felt.

In Japanese records we read of the burrowing of moles before an earthquake, the rising of fish to the surface of the water, and other unusual movements in animals as having been observed to precede the phenomenon. To give a description of similar observations in other countries and cities referring to unusual movements which have been observed in dogs, horses, oxen, mules, pigs, geese and other animals before the coming of an earthquake, would take too long for the purpose we have before us. Another subject of interest, and one which has given rise to much speculation, are the movements of the barometer and thermometer which appear often to have been observed at or about the time of an earthquake. In Japanese accounts of earthquakes we read of unusually high temperatures, a largeness in the appearance of the stars, mirage, illumination of the sea, and kindred phenomena as having occurred at or about the time of a great earthquake. In other countries sometimes a rise in the barometer has been observed; at other times a fall, and sometimes no change whatsoever. Before our last great earthquake we appear to have had a somewhat low barometer. If, however, we refer to the writings of M. Perrey as analysed by Mr. Mallet, we shall see that there have been as many instances where the barometer fell as where it did not fall, and we are led to the irresistible conclusion that as yet we have not sufficient foundation on which "to base a law with respect to the behaviour of a barometer during an earthquake." However, that a relation may exist is not improbable. That there is a momentary *mechanical* movement in a barometer at the time of an earthquake is a fact very distinctly shown upon the curves drawn by the barograph at the Yamato Yashiki observatory.

With regard to the thermometer and the connection of its movements with earthquakes we again find ourselves unable to establish any rule. The Greeks and Romans believed that earthquakes were most prevalent in the warm seasons while we believe they preponderate in the cold. If we tabulate all the records we are able to obtain of earthquakes which have occurred in Japan since early times, we shall find that the greater number of them have happened during the warm seasons, whilst if we tabulate the smaller earthquakes which are now being recorded we shall find that the greater number happen during the winter months.

In what manner changes of atmospheric temperature can be connected with earthquakes it is difficult to conceive, unless, as has been suggested, they may sometimes indicate a local overheating of super volcanic districts. Changes like these, however, assuming them to exist, could hardly be supposed to be unconnected with the seasons.

The relations between the rainfall and earthquakes of Japan which have been sought, do not appear to have, as yet, shown any satisfactory connection. It does not seem to be altogether beyond the pale of possibility that the rain which falls upon a volcanic country may have an influence either in soaking downwards and becoming converted into steam, or in simply loosening the ground. From personal experience I have found that microphones buried in pits during a heavy shower of rain are sometimes very active, as if by the soaking downwards of the rain and perhaps the falling in of small particles of earth from the side of the pit the microphones had been slightly shaken.

At the time of earthquakes, high winds have often been observed, and from the tables given to us by Mr. Knipping it would appear as if these two phenomena had been synchronous. About the electrical effects which are produced at the time of an earthquake we have as yet but little record, nevertheless from what has been observed in other countries there is every reason to believe that we have in Japan the means of making observations which may lead to interesting results. The momentary current produced in cables and telegraph wires at the time of an earthquake was brought before our notice some years ago by Mr. W. E. Ayrton in a communication to the Asiatic Society. In Japan it is a popular belief, and a belief which is said to be founded upon well authenticated observation, that shortly before an earthquake a magnet is affected by losing its power of attraction. Analogous effects appear to have been observed in other countries, and amongst those who have remarked upon this subject we may note the names of Humboldt, Arago, and Biot. So far, the conclusions which have been arrived at appear to be that the observed disturbances are due rather to mechanical agencies than to variations in magnetism. However, as the belief that there is a connection between earthquakes and magnetic force has taken such deep root in the minds of many who dwell in earthquake shaken countries, although we can only dimly discern the possibility of such a connection, the subject appears to be worthy of investigation.

In the accounts of some Japanese earthquakes, mention is made of the appearance of luminous bodies in the sky and shooting stars. Humboldt and Mallet have each made reference to similar phenomena, but the results obtained distinctly show that there have been many more earthquakes unaccompanied by such appearances than occurring with them. In Dr. Naumann's valuable paper on the earthquakes of Japan, reference is made to the same subject, but the results obtained, although in many case showing connections to exist, are of such a nature that the question nevertheless appears to remain open. Notwithstanding the observations of Wolf a similar remark may be made with regard to the connection which exists between the periods of earthquakes and those of sun spots.

The connection which might exist between earthquakes and the sun and moon was many years ago worked out by M. Perrey, and his results examined by a commission appointed for the purpose by the French Academy of Sciences. It was supposed by M. Perrey that the sun and moon exerted an attractive force upon the crust of the earth, just as it does upon the waters of the ocean, and caused it to swell until meeting with resistance, the formation of fractures resulted and hence the production of earthquakes. By analysing the various catalogues he had collected, and comparing them with the motions of the moon, amongst other results which were arrived at, he came to the conclusion that earthquakes were more numerous when the moon was in perigee than when in apogee. To these results, however, an anomaly now and then presents itself, and no better example of such an anomaly could we have than that which has been pointed out by Mr. W. S. Chaplin in regard to the earthquakes which have recently occurred in this country, which are in utter discordance with any of the results obtained by M. Perrey.

Thus far, then, it would seem that the curves and tables which have been drawn in Japan, like those which have been made in other countries, have not, as yet, brought us to any definite results, and so far as we have gone we have only reached conclusions similar to those expressed in 1850 by Mr. Mallet, who then said, as the result of his investigations, that "earthquakes and volcanic eruptions may occur at any time of the day or year."

If such, then, is the case would it not be well, whenever problems like these we have been considering are brought before us, to attack them first in an opposite direction, and, instead of first collecting facts and then reasoning up to generals results, to picture to ourselves the result we are endeavouring to reach and then inquire whether it would be reasonable to seek for facts which would lead us to it. For example, let us suppose ourselves searching for a connection between earthquakes and the attractions of the moon; instead of at once proceeding by the accumulation of facts to see if such a connection had a reality, might we not proceed backwards, and ask ourselves if it would be reasonable to expect that a result like this could ever be attained? Is it likely that the attractive power of the moon is so great that it could draw up the crust of the earth beyond its elastic limits? We know what it can do with water. It can lift up a hemispherical shell 12,000 miles in length about two or three feet higher at its crown than it lifts the earth. Even supposing the solid crust to be lifted 100 times the apparent rise of the tide is it likely that a hemispherical arch 12,000 miles long when it is raised 200 feet at its crown could by any possibility suffer fracture? If an arch is 12,000 miles in length all that we here ask is whether the materials which compose the arch are sufficiently elastic to allow themselves to be so far stretched that the crown may be raised two hundred feet. The result which we should arrive at is apparently so obvious that actual calculation seems hardly necessary. If we regard the earth as being solid, the question resolves itself into the inquiry as to whether a column of rock, which is equal in length to the diameter of the earth, or about 8,000 miles, can be elongated two hundred feet without a fracture. This is equivalent to asking whether a piece of rock one yard in length can be stretched one seventy thousandth of a foot. Considering that this is a quantity which is scarcely appreciable under the most powerful of our microscopes, we must also regard this as a question which it is hardly necessary to enter into calculations about before giving it an answer. To vary the method of treating such a question might we not ask what is the utmost limit to which it would be possible to raise up, or stretch the crust of the earth without danger of a fracture? Thus, for instance, to what extent might a column of rock be elongated without danger of its being broken. From what we know of the tenacity of materials like brick and their moduli of elasticity, it would seem possible to stretch a bar of rock 8,000 miles in length for approximately half a mile, before expecting it to break. As to whether there is a wave the height of which is equal to half this quantity running round our earth as successive portions of its surface pass beneath the attracting influence of the sun and moon, is a phenomenon which, if it exists, would probably long ago have met with a practical demonstration. Finally, knowing the mass of the moon and the other bodies which exert any important influence upon the earth, we might calculate at any time their attractive force and if this were done I think we should find that the stretch it might produce was something far below the elastic limits of the materials on which it acted. We might therefore perhaps conclude that influences like those we have been considering would if taken by themselves be far too small to directly concerned in the production of earthquakes. How far they might be influential in causing shocks to take place at particular *times* is another question, the answer to which might be conceived of by first answering the questions already given. The cases which I have here chosen are purely hypothetical and are only brought forward to illustrate the manner in which such a subject might be treated.

The deformation which a spherical shell or solid globe like our earth would experience under the action of a body like the moon has already been treated mathematically by Lamé Thomson and others and it would seem that much might be derived, by attacking many other questions which are analogous to it in a similar manner.

If we now turn from the observations themselves to the instruments which were used to make them. I think that young as we are in the world of seismic science, we shall see around us a mighty forest of pendulums, springs, and delicately balanced columns, all intended to indicate some of the phenomena which accompany an earthquake. For the small shocks which so often visit us Mr. Knipping has found, and I think that Mr. Chaplin and I support him, that any of the simple seismometers, like columns perched on end, are but of little value as indicators. Let our columns be so small that it is with difficulty we can make them stand, yet strange as it may appear, it is but seldom that they fall. And even when they do fall, it is often difficult to say that they indicate to us any thing more than the fact that there had been a shaking. If we could guarantee their having fallen at the first impulse by their bases having been, so to speak, swept from under them, then not only would they tell us the direction of the shock, but also the point from whence it came. In small columns such as it is necessary to have if we are to expect any effect whatever, there are the mechanical difficulties of obtaining a base which shall be perfectly flat and at the same time at right angles to its axis. If these conditions are not fulfilled, the direction in which we find our column lying after a shock will indicate but little. What is required is to have a column with a base so large that it can be easily stood on end, and what is more important, to make the column of such a shape and height that for its maximum "tip" it shall have a period quicker than that of the earthquake. By making columns of different shapes this has been to some extent, accomplished.

Amongst the instruments of a more complicated nature, we may mention Palmieri's well known assemblage of springs and pendulums, of which we have an example working at the government observatory of Yamato Yashiki. Amongst private workers a heavy pendulum appears to have been a favourite instrument, and at the present moment there are perhaps a dozen of such instruments which have been working for some time.

In nearly all the older instruments which have been constructed upon the principle of a pendulum, it has been assumed that during a shock the pendulum would swing, and that the first swing would indicate to us the direction of the earth's motion. From numerous experiments upon upon pendulums varying in length from thirty feet down to one foot, experiments that have been confirmed by other observers, I find that during the small shocks which are felt in Tokio, no visible swing is to be observed. If, however, the shock is strong and long, like that recently experienced, a motion is gradually got up, and a pendulum, even if it is forty feet in length, and loaded at the end with a weight of 80 lbs., like a pendulum which, through the kindness of Professor Marshall, I have been experimenting with in the Physical Laboratory of the Kobu Dai-Gakko, will get up a long and steady swing. This appears to be due to the swing of the building in which the pendulum is suspended, being nearly in unison with the period of the pendulum. The reason that these pendulums do not swing during a small shock is apparently because their period of vibration is long compared with that of the earthquake, and that the house in which they are suspended to a great extent absorbs the vibrations by the viscosity of its joints and thus prevents any movement in the point of support. During a small earthquake it would therefore seem that we may regard the bob of a heavy pendulum as a steady point above the moving earth. In two pendulums which I have suspended, the motion of the earth is recorded by a pointer from the pendulum marking upon a piece of smoked glass moving beneath it. In a third pendulum the motion of the earth is indicated by the earth pushing a small pointer against the steady pendulum; the pointer being moved, a mirror with which it is in contact, is caused to revolve and deflect a beam of light. In Dr. Wagner's apparatus which so far as I am aware is the first where the pendulum principle in conjunction with a mechanism for magnifying the earth's motion and for checking any oscillations of the pendulum has been employed, we have a pendulum below which there is attached a second smaller pendulum or lever the shorter arm of which works in the base of the pendulum above it. The longer arm of this lever magnifies the earth's motion; a second portion of the apparatus gives a close approximation to the direction of the shock, and a third portion the vertical motion. To understand the working of these several parts it will be well to refer to their description as given by Dr. Wagener himself in the communication referred to at the end of this paper.

Mr. Ewing's seismograph, which he is about to exhibit to the society, is designed to draw two curves representing on a magnified scale two rectangular components of the horizontal movement of a point on the surface of the earth, in conjunction with the time. These curves are drawn by means of two levers, with their short ends in contact with the bob of a long pendulum, and with their long ends free to slide across two surfaces which are kept moving continuously and uniformly by clockwork.

In Mr. Gray's apparatus small threads are carried from the end of the bob to small pulleys with pointers. These pulleys being drawn away from the pendulum during the motion of the earth, they are caused to revolve. The pointers are then left in the position to which they have been moved. As this pendulum is attached at its upper end to a strong spring, a vertically placed thread from the centre of the weight to a pulley fixed above the point of suspension, tells us something about vertical motion.

The first pendulum observations which were made in Japan appear to have been by Dr. Verbeck in 1872 and 1873 who used a pendulum about six feet in length. This investigator also used a heavy block of wood resting on four crystal balls, the whole being carried on a marble slab. At the time of an earthquake the block of wood by its inertia remained stationary and by means of a sliding pencil marked the motion of the earth upon a sheet of paper placed upon the moving slab.

With machines such as these, many measurements which tell us something about the actual horizontal motion of an earth particle have already been obtained. As examples of such observations I give the following.

The first four are taken from my own observations, whilst the second three are some which have been observed by Mr. Knipping as recorded by the instrument of Dr. Wagner.

	1.	2.	3.	4.
Date	1879, March 4th	1879, October 18th	1879, October 25th	1880, February 1st
Time	4.43 p.m.	2.0.11 a.m.	0.39.0 a.m.	11.0.0 p.m.
Extent of motion	2 mm.	4 mm. to 5 mm.	4 mm.	1.25 mm.
Direction	N. 10° E. to S. 10° W.	N. N. W. to S. S. E.	N. 28° E. to S. 28° W.	N. 25° W. to S. 35° E.

	1.	2.	3.
Date	1879, October 17th	1879, November 22nd	1879, December 3rd
Tokio Meantime	13 h. 58 m. 30 s.	9 h. 25 m. 42 s.	19 h. 8 m. 18 s.
Greenwich Meantime	4 „ 39 „ 22 „	0 „ 6 „ 34 „	9 „ 49 „ 10 „
Maximum Horizontal Movement	2.3 mm.	1.7 mm.	4.3 mm.
Maximum Vertical Movement	.06 „	.0 „	0.13 „
Total Movement	2.3 „	1.7 „	4.3 „
Angle of Emersion	1.6°	.0	1.7°
Direction	N. 1° E. to S. 1° W.	S. 80° E. to N. 80° W.	S. 21° E. to N. 21° W.

Hitherto the amplitude of an earth particle appears only to have been obtained from inferences based upon the extent to which fissures have been formed in non-elastic masses of masonry and brick work. If this is the case, we may congratulate ourselves upon having already made an important advance in seismic science.

In all the instruments which have hitherto been employed in Japan one or two principles appears to have been followed. First, we have had instruments whose operation, so to speak, depended upon a certain portion of their parts remaining steady. Of this class we have the pendulums just described. We also have a heavy weight suspended at the end of a bracket as experimented on by Professor Chaplin. In the other class we have bodies whose main feature is their movement, amongst which we have the swinging pendulums, both liquid and solid, and falling bodies like columns. The year before last a new principle was brought before us by Messrs. Perry and Ayrton who, with great justice, described it as a "neglected principle." Its feature appears to be as follows:—If we take a vibrating body like a spring and it be set in motion during an earthquake, not only will it have a motion of its own, but it will have a compound motion, the components of which are its own natural vibrations together with those implanted upon it by the earthquake, and knowing what the former of these is, the latter may be separated by analysis. The true principle involved, as ennunciated by the authors, may be understood by the following two illustrations.—Let a man walk across a springy plank. If he walks quickly or attempts to run, the motion of the plank will not synchronize with his steps, and he will be in danger of losing his foothold. If, however, he walks slowly, the plank will give with each of his steps, and register the periodic motion of his movements. Now if we imagine the steps of the man to represent the vibration of an earthquake, we see that these can only be distinctly reproduced upon a spring like the plank when the period of the earthquake is less than the period of vibration of the spring. If, therefore, we wish to imitate the earthquake motion by means, say, of a ball fixed upon a spring, this spring must have a quicker period of vibration than that of the earthquake.

Hitherto all earthquake machines which have been in any way dependent upon springs have had slowly vibrating springs, so that the earthquake motion, if it had ever been extracted from the results which were obtained, would appear like ripples upon the sides of large waves.

Here is an illustration in which both the old and the new principles are combined. Let any one shake a young tree. The trunk, which is naturally a stiff, quickly vibrating body, will shake with periods which are given to it by the shaker, whilst the branches will all have different motions, depending on their thickness, position and length. The thin ones will nod to and fro with a slow period of their own, whilst the thicker ones will move more quickly, and if their natural period of vibration is quicker than those vibrations which are given to them by the trunk, they also will record the motion of the shaker. Where a tree is shaken by an earthquake exactly the same thing will occur, the trunk and thick branches are very likely to move with it, and record its motion, whilst the thin branches nod to and fro with motions of their own.

Now many of the earthquake instruments which have hitherto been constructed, seem to work on the same principle as the thin branches, whilst that proposed by Messrs. Perry and Ayrton is represented by the thicker branches and the trunk. One simply shows that there is a motion whilst the other gives the real motion.

The paper of Messrs. Perry and Ayrton has suggested to us an instrument which will give us time observations, of the number of vibrations which occur in any given, interval, and their relative amplitudes. From the fact that a machine of this description has not yet received a trial, it is sincerely hoped that the members of the Seismological Society may speedily have an opportunity of testing an instrument which promises so much.

If we except those seismometers which may be constructed on the principle just mentioned, the difficulty to be overcome appears to be, in obtaining at the time of an earthquake a steady body upon which to write the observations, of the moving earth, or, *vicè versa*, to obtain a steady body from which, by means of a pointer, we can trace out the motion of the moving earth upon itself. In the case of pendulums if it is found that the point of support receives so much motion that they are caused to move. This to a great extent might be obviated by depending the point of support from a net-work of india rubber bands, which net work might, in turn, be depended from a second set of bands, the numbers being increased until found sufficient to eat up all small vibrations of the earthquake. It has been suggested that a similar result might probably be arrived at by a series of pendulums dependent from each other, the periods of each being incommensurable with the one immediately above it, and the top one with the period of the earthquake. As a third method of obtaining a steady point at the time of an earthquake, it might perhaps be possible to use a gyrostat.

With regard to the period of an earthquake, that is to say, the rapidity with which its vibrations succeed each other, I may remark that, although no results upon this subject have hitherto been published in Japan this interesting problem has, for some time past, been a subject for speculation and work. Besides the moving plates beneath the large pendulum, which have already roughly indicated facts which will be useful in the solution of this problem, experiments have been made with a number of extremely short pendulums to determine which of them, by its movement, was in accordance with the movement of the earthquake.

As other methods of attaining the same result, Mr. Gray and myself are using a number of vertical springs so loaded that their periods of vibration are different, and it has been already shown by the last few earthquakes, that it is only springs of particular periods which are caused to vibrate.

Another interesting study for those living in earthquake shaken districts are the effects which are produced upon buildings, and the best means to be employed for avoiding such effects. We are all no doubt acquainted with the system which is employed by Mr. Lescasse in order to render a building proof against all ordinary shakings. As an example of such a building we have the offices of the Mitsu Bishi Company now in process of erection. As another example of work in the same direction we have the pamphlet of Messrs. Perry and Ayrton who discuss the principle of relative vibrations in the various parts of a building. I may here remark that the actual vibration of a wooden house during the last great earthquake, seemed to accord with the calculated vibration as given by the above authors.

With regard to the cracks which have been produced in buildings, I may remark that they form an interesting subject for investigation. In making observations on a large number of houses in the neighbourhood of the Ginza, and for assistance in making which observations my best thanks are due to Mr. Josiah Conder who accompanied me, I found that the greater number of cracks were visible in those streets which were traversed parallel to their length by the greater number and the more severe earthquakes, whilst the streets at right angles to them had suffered least. Several of the more modern and elaborate constructions which we have in Tokio have also been examined, but about these nothing has, as yet, been published.

Before concluding, as it may be of interest to many who are here present, I will make a few remarks about a scheme which is now being carried out with regard to the earthquakes which visit the district round Tokio and Yokohama. This I will supplement with some speculations as to probability of our ever being able to forewarn ourselves with regard to such phenomena.

Through the interest taken in Seismological Science by Mr. Yamao Yozo, the minister of public works, fifteen seismometers of the pendulum type as designed by Mr. Gray, are now being constructed for the purpose of distribution over the plain of Musashi. Through the kindness of Mr. Ishie, the director of the telegraph department, these instruments are to be placed in the telegraph offices, where, by means of clocks which are every day regulated by Tokio time, not only will the earthquake movement be recorded, but the times at which the shocks are felt will be also noted.

By this means it is hoped to obtain very close approximation to the actual movement at each place. The relative movements at different places will also be known, the determination of which latter fact will, in itself alone, be sufficient to place Japan among earthquake shaken countries in the first ranks of those which have paid attention to observational seismology.

From the direction of the shock as observed at different stations its *epicentrum* may be found, and the district or districts from whence come all the shocks we so often feel may be determined. Time observations might bring us to similar results, but what is of more importance, they will give us the rates at which a given shock is propagated in different directions, and by variations in these rates we may obtain a clue as to the nature of geological formations buried deep beneath our view.

The determination of problems like these are of the greatest interest to science, and the practical results will be of value to the geologist, the builder, and the engineer.

Let us now proceed a step farther and enter into what many would call pure speculation. Supposing that the areas from which the shocks originate which so often visit us were localised. I think if we were to place our seismographs on such a spot we should record many earthquakes which are too feeble to travel far out into the surrounding districts. In Yokohama earthquakes are felt which seemingly expend their energy and die out before reaching Tokio. On the area from which these feeble shocks have emanated it is not at all unlikely that still feebler shocks might be recorded which could not even reach Yokohama. And if in such a district we were to use some form of micrometric seismograph, we might perhaps record such feeble tremors to which the ordinary seismometer would have been insensible.

Next let us ask ourselves what is it that produces the earthquakes and earth tremors in a seismic district? Is the ground continually crackling and breaking as it bends beneath increasing strains, as for instance the expansions and contractions produced by a flow of heat? If this is so, observations upon earth temperatures may possibly yet become the means of indicating to us the approach of breakages which snapping the rocky crust give rise to earthquakes. Whether by observing the temperature of hot springs we may come to similar results, it is difficult to say. In every probability hot springs represent to us the escape of water from reservoirs under pressure, and when such is the case variations in the temperature of the waters underground could not well be expected to show themselves in the water as it escaped at the surface. If underground temperatures are to be derived from sources such as these the springs must be well chosen. Mr. Arai Ikunosuke the director of the observatory at Yamato Yashiki I am happy to say has the intention, when a suitable opportunity presents itself, of putting these suggestions to the test. I am informed that in Bourbon they have yielded results which are highly satisfactory.

Instead of working with earth temperatures we might perhaps, be more successful if we formed a study of earth *remors* which may possibly be found to indicate the breaking of the ground as crackling indicates the breaking of a stick.

These are hypotheses which yet need careful study, but should they ever prove to be correct, as the temperature or crackling in a seismic area increases, we may yet see a large black ball gradually ascending a tall staff to warn the inhabitants on land of an approaching earthquake, with as much certainty as the ball upon a pole at many sea-ports warns mariners of storms at sea.

I have already stated that the relations which have been sought as existing between earthquakes and phenomena, like the motion of the moon, the rise and fall of the barometer and the like, are as yet too indefinite to be considered as established. As the attempts to establish these connections have been numerous, would it not be well to vary our operations, and see if the laws for which we have been searching may not be found by comparing the occurrence of earth *tremors* and these phenomena rather than earth *quakes* ?

When we consider the nature of the pull which the moon exerts upon our planet, we are more likely, I think, to find a connection between its motions and earth *tremors* of some sensitive district, than between such periods and earth *quakes*.

As the earthquakes which produce sea waves, of which the old residents in Japan have had several experiences, often take place at such great distance, it ought often to be possible by means of the telegraphs which are now stretched in all directions to forewarn ourselves and others of the approach of the waves notwithstanding that they traverse deep oceans at the rate of several hundred miles per hour. About May 11th, 1877, a series of sea waves swept in upon the shores of all the islands in the Pacific, from New Zealand in the south to the Kuriles in the north. Here and there where the bays were long and narrow the waters inundated villages, and the property which was destroyed was very great. This particular series of waves, we subsequently learnt, originated on the coast of South America, on May 9th, and having to traverse 8,000 miles of ocean before they reached Japan they had taken more than 24 hours. An example like this shows us that telegraphic communication might easily be made the means of providing against calamities arising from such an origin.

On a smaller scale if it should be thought desirable we might, in a similar manner, warn ourselves against many land shocks. For a shock to travel from Yokohama to Tokio, passing directly through the two places, it would have to traverse about fifteen miles of soft earthy and rocky strata, to do which it would probably take a minute and a half. Round Tokio and Yokohama we have at the present a ring of telegraph stations at distances of from 20 to 60 miles. To cause a shock as it passed any of these stations to complete an electric circuit would be a matter very easy to accomplish. Such a current being completed it might almost instantaneously be made to fire a gun in Tokio or Yokohama, and the inhabitants of these places would thus have from two to six minutes warning of at least a large proportion of all the shocks which visit them. The nature of the shock which was to be expected would, to a great extent, depend upon the adjustment of our instruments. If the instruments were delicate we might often be alarmed at hearing the report of a cannon and afterwards only receive a tremor. To make a contrivance like this practical it would be necessary so to construct it that the circuit could only be completed by a shaking that was tolerably severe, and that the cannon had a report easy to distinguish. These last remarks have been made, not with the hope that I shall ever see them realized, but with the hope that they may help to convince those who regard the foretelling of an earthquake as a problem too difficult to be solved, and to show them it is by no means so utterly beyond our reach as might, at first sight, be anticipated.

And now I will conclude. What I have attempted has been to show the position which the study of earthquakes and volcanos occupy in the scheme, waiting to be worked out, for the elucidation of the natural laws upon which all terrestrial things appear to be dependent.

After this I have given a condensed summary of the work which has been done in this country towards carrying out this scheme, in doing which it is my sincere hope that brevity has not led me into inaccuracy or injustice.

The study which is before us is extremely great, and is one which offers a wide field both for observation and speculation. Hitherto, although the facts which have been amassed are very numerous, the results which have been obtained are comparatively small. One cause which has undoubtedly been powerful in preventing advancements such as those which characterize other departments of science has been the fact that seismic and volcanic phenomena have never been prominently brought before those nations distinguished by their attention to scientific subjects. Here, however, in Japan we have a large body of men, all of whom are more or less interested in scientific matters, dwelling in a country where these phenomena, are ever present. The field to work in is large, and as we are in it, it is earnestly to be hoped that we shall take advantage of our opportunities and, by endeavouring to unravel some of the tangled problems of seismic science and by increasing knowledge, add at least a mite to the understanding of those laws which ameliorate the conditions under which we live.

Note.—Recent publications on the Earthquakes and Volcanos of Japan, referred to in this paper.

Proceedings of the German Asiatic Society. (Mittheilungen der Deutschen Geschellschaft für Natur und Volkerkunde ostasiens.)

14tes Heft.—"Verzeichniss von Erdbeben, wahrgenommen in Tokio, Japan, in 35° 41′ N. B. 139° 47′ O. L. v G. von September 1872 his November 1877 von E. Knipping.

15tes Heft.—"Ueber Erdbeben und Vulcanausbrüche in Japan, von Dr. Edmund Naumann.

15tes Heft.—"Bemerkungen ueber Erdbeben messer und Vorschlaege zu einem neuen Instrumente dieser Art," von Dr. G. Wagner.

Transactions of the Asiatic Society of Japan.

Vol. II.—Also. Vol. III, Part II.—Constructive Art in Japan' by R. H. Brunton, Esq.

Vol. V, Part I.—"On a neglected principle that may be employed in earthquake measurements," by John Perry and W. E. Ayrton.

Vol. VI, Part II.—"Destructive Earthquakes in Japan," by I. Hattori, Esq. "Notes on some of the Volcanic Mountains in Japan," by D. H. Marshall, M.A. "An Examination of the Earthquakes recorded at the Meteorological Observatory, Tokiyo," by W. S. Chaplin, Esq.

"Some remarks on constructions in brick and wood, and their relative suitability for Japan," by George Cawley, Esq.

Geological Magazine.

Dec. II. Vol. I No. 5.—"A visit to the Volcano of Oshima," by J. Milne.

Dec. II. Vol. V No. 8, also Dec. II. Vol. VI No. 11.—"On the form of Volcanos," by J. Milne.

Dec. II. Vol. VI. No. 8.—"A cruise among the Volcanos of the Kurile Islands," by J. Milne.

Other Publications.

"Reports of the Geological Survey of Hokkaido" by Benjamin Smith Lyman.

"Reports of the Geological Survey of Japan," by Benjamin Smith Lyman.

Pamphlet printed at the Imperial College of Engineering, Tokei, Japan. "On Structures in an Earthquake country," by John Perry and W. E. Ayrton.

Pettermann's Mittheilungen 1876, Heft. 10. "Der Fujiyama und seine Besteigung" von J. Rein.

Deutschen Geologischen Gesellschaft, 1877. "Die Vulcaninsel Ooshima und ihre jüngste Eruption," von Herren Edmund Naumann in Yedo.

Mineralogische Mittheilungen 1877. 1 Heft. "Bemerkungen ueber die Japanische Vulkane, Asama Yama, Takiyama, Iwa-wasi Yama und Fusi Yama." Von Dr. Richard von Drasche.

"An Essay on Japanese buildings and on buildings in general, considered in connection with earthquakes; and a description of a system designed to give security to constructions in masonry," by J. Lescasse. Published in the *Japan Gazette*, March 29th, 1877.

The earthquake of Dec. 3rd, 1879. *Japan Gazette*, Dec. 13th, 1879.

The earthquake of Feb. 22nd, 1880. *Japan Gazette*, Feb. 24th 1880.

THE chairman said he was certain that in tendering thanks to professor Ewing for his elaborate description of the new seismograph he only echoed the sentiments of the meeting. The general principal of the instrument was similar to that of the heavy pendulum, and the main question was whether or not the pendulum will oscillate or whether it remains steady and thus allows the vibrations of a small earthquake to be recorded. In Tokio a number of light shocks have been felt which failed to set a heavy pendulum in motion; but by a severe shock the same pendulum oscillated through a large angle. In professor Marshall's laboratory there was a pendulum forty feet in length, which was set in motion by the late severe earthquake and kept oscillating for a period of eight hours. He (the chairman) was of opinion that professor Ewing's machine was much better than any instrument of the kind which had come before his notice.

Professor Knipping said that with regard to what professor Ewing had mentioned about the suspension of the heavy pendulum, he quite agreed with him that the point of suspension should be as rigidly connected with the earth as possible, so that every movement of the earth's surface should also be made at the same time by the point of suspension. But the length of the pendulum in Dr. Wagner's apparatus was not nearly twenty feet, as that of Professor Ewing's, but was only about three feet long; and from observations made during a period of about two years he (Mr. Knipping) was rather confident that a pendulum three feet in length was quite long enough. It was not every person who had a clear height of twenty feet at his command; and even if he had that height at his disposal, it would require a very broad basis of strongly bound frame-work to prevent the point of suspension going its own independent way in an earthquake. Although the apparatus he had been observing for some years could give no direct and positive proof of the pendulum remaining in the same place in space during an earthquake, while the point of suspension moves to and fro, there has been nothing observed yet which points to the contrary, while everything is in its favour. Another apparatus, still in course of construction, will very likely prove definitely whether we are right in assuming that in moderate and even in strong earthquakes, a heavy pendulum remains practically at rest. But even should it be proved afterwards that in extreme cases the heavy pendulum commences to swing, instead of remaining at rest, he was not of opinion that the whole apparatus should be rejected. Even such observations may be used; and it is possible to separate in the diagram made by the instrument that part due to the earthquake motion from the other part due to the swing of the pendulum. Dr. Wagner's apparatus, described in the 15th vol. of the "Mittheilungen der Deutschen Gesellschaft," consists of several parts,—

1st.—For the greatest horizontal motion of a point in the earth's surface; at the same time it arrests a clock.

2nd.—For the greatest vertical motion.

3rd.—For the direction in azimuth.

4th.—A registering apparatus for marking the duration and intensity of each vibration, and also the duration of the whole earthquake. No. 4 has not yet been put up, but 1 to 3 have been some time at work and seem to answer very well.

Professor Mendenhall said he thought that there ought to be some systematic method of examining such machines as that which had been exhibited by professor Ewing, and the committee of the society had thought it advisable that such instruments should be submitted to a sub-committee, who should make an exhaustive study and elaborate report on the machines. And as they had now a very interesting and valuable seismograph, he rose to move that a committee of three be appointed to examine this instrument; and that this committee shall examine into and report on the value of the following points:—

Value of results to be obtained by its use.
Scope or comprehension of these results.
Reliability of the results.
Sensitiveness.
Simplicity of operation.
Simplicity of construction.
Cost of construction.
Skill required in its use.
Any other points of interest or importance.

These were some points which he (professor Mendenhall) had noted down, and they might be taken with any others which would suggest themselves to the committee. The committee should make the examination and give in their report at as early a date as possible.

Professor Ewing said that he should have much pleasure in giving every assistance in his power to such a committee. He had not the slightest objection to having his instrument reported upon, but begged to remind the meeting that it was not yet completed. The room in which it was to be placed was not finished, neither was the clock which had to drive the mechanism. It was, therefore, not in a fit state for examination, and on that account he thought professor Mendenhall's motion rather premature. He also thought that in all cases when a committee is appointed to report on an instrument, that their report should be submitted to the inventor, who should have the privilege of criticising such report simultaneously with its presentation to a public meeting.

Professors Knipping, Marshall and Chaplin were then appointed a committee to examine into the merits of Professor Ewing's invention.

There being no other business the meeting adjourned, after having sat for nearly two and a half hours.