supposed, although they often pass muster under erroneous names. Tourmaline is sold as ruby, cinnamon stone as jacynth, white jargoon and phenacite as diamond, while green garnets are universally known in the trade as olivine or peridote.

That the varieties of available gem-stones are not far more numerous, is due mainly to the prejudice of purchasers, who ring the changes on diamonds, rubies, sapphires, and emeralds, and have heard of nothing else; estimating the stones, as the public estimates popular actors or authors, not by their real excellence, but by their names.

In the mineral gallery of the British Museum are many examples of cut stones which have rarely or never been employed in jewellery, but should certainly win favour on their own merits.

One very curious example is a little gem cut from a crystal of the ordinary tin-stone, the same ore which is worked for tin in the Cornish mines. This is a stone which, when cut from a sufficiently transparent crystal, possesses a most beautiful lustre and colour.

As another example, I may mention a stone which, I suspect from its appearance, would make a very beautiful gem. It was sent with some other fragments from the ruby mines of Burmah; it is only a single rough fragment, and has completely puzzled every one to whom I have shown it. By means of the very tests which I have been describing, and without sacrificing more than a pin's point of the stone, I have been able to identify it as the boro-silicate of lime known as Danburite. This mineral, if it has ever been used in jewellery. which is most unlikely, has certainly never been rightly named.

(A number of facetted stones lent by Mr. Gregory, who has made many interesting experiments in this direction, were thrown upon the screen by reflected light; among these were several of the less familiar gems, such as tourmaline, chrysoberyl, phenacite, felspar, andalusite, axinite, spodumene, sphene, and idocrase.)

I do not know whether the final impression produced by what I have said, is that the determination of stones is an easy or a difficult thing. The impression which I wished to convey, is that where these scientific tests can be applied, it is an absolutely certain thing; and where they cannot be applied, there is no such certainty.

The crystals from which these gems are cut are changeless and imperishable, their beauty has been enhanced by the art of man, but they have lost none of their wonderful properties in the process; in fact, it is only by utilising these very properties that the lapidary converts them from dull stones to flashing jewels, and it is by these properties that we have to recognise them.

The ruby formed countless ages ago in the heart of Burmah, is the same thing in all essentials as the ruby formed to-day in a Paris laboratory.

It is curious to reflect that the diamond which to-day glitters in a London ball-room, may have adorned the crown of some Oriental monarch centuries ago—may have been picked from the shores of an Indian stream in the dawn of civilisation—may have been the silent witness of the growth and decay of empires—but by its own unchanging existence has always borne steadfast evidence to the everlasting laws of nature.

H. A. MIERS.

THE OBSERVATION OF EARTH-WAVES AND VIBRATIONS.

THE object of this communication is to call attention to the apparently high velocity with which motion is transmitted from an earthquake centre to places distant from it a quarter of the earth's circumference, and to the importance of instituting an extended systematic observation of these movements.

During the last few years Dr. E. von Rebeur-Paschwitz and other observers in Europe have recorded earth movements which had their origin in Japan or in other distant countries. Beyond a radius of a few hundred miles from their origin these disturbances are often too feeble to be sensible or to be recorded by ordinary seismographs. Their presence is, however, made known by the use of specially contrived nearly horizontal pendulums, and by these and other instruments we find that they usually have a duration of from ten to thirty minutes, though now and then they last one or two hours. On June 3, 1893, the writer obtained a record lasting 5 hrs. 24 min. In Europe what was probably the same disturbance indicated a movement which continued for about fifteen hours. From observations hitherto made, it seems extremely likely, as Dr. E. von Rebeur-Paschwitz has suggested, that these earth-waves could be recorded at almost any point upon the surface of our globe, while the phenomena they present are such that it is probable that their extended study would throw light, not only upon the manner in which motion is transmitted through the superficial portions of the earth, but also across its interior.

As illustrative of the results to which these records lead, I take those derived from diagrams of several seismographs in Tokyo, and from that of a long pendulum seismograph at Rocca di Papa in Italy, which on March 22, 1894, together with many other instruments in Europe, exhibited considerable motion. The origin of the disturbance was off the N.E. coast of Yezo (Lat. 42° N., Long. 146° E.).

From observations made in Tokyo, distant about 600 miles from the epicentrum, not only upon the initial disturbance, but also four after-shocks, it seems that motion was propagated at an average rate of about 2·3 km. per second. Inasmuch as the instruments from which these records were obtained, are not capable of recording movements of small amplitude, probably this velocity was that of the pronounced vibrations of the quasi-elastic nature characteristic of most earthquakes. There are reasons for believing that such waves outside an epifocal area are practically confined to the surface of the earth. A movement which from the manner in which it slowly affected ordinary or horizontal pendulum seismographs, had probably a similar character, travelled from Japan to Italy with a velocity of from 2·7 to 3 km. per second, the larger waves travelling at the slower rate.

Preceding these decided motions, minute tremors were observed, which, if they originated at the epicentrum and travelled on the surface of the earth, must have done so at a rate of 11·5 km. per second, while if they were created by the transformation of the energy of the partially elastic undulations as they passed from medium to medium, then their velocity of propagation must have been still more abnormal. If it is assumed that they reached Italy by direct radiation through the earth, or that in consequence of refraction they followed curvilinear paths, the observations indicate a velocity of 9 or 10 km. per second.

Considering the influence of gravity upon the propagation of surface undulations, the observed velocities may possibly be a little lower than what might have been expected. The minute tremors, however, seem to have a velocity which is roughly twice that for a condensational rarefactional wave in glass.

Observations upon other earthquakes, although none of them can claim any great degree of accuracy, point to the same general results.

At present, the diversity of instruments employed in Europe, and the various degrees of sensibility given to the few instruments which are approximately similar, apparently results in the recording of different phases of motion, and it is not likely that our knowledge will be increased or made more accurate until there is greater uniformity in the methods of observation.

Now to determine whether the disturbances created by large earthquakes are propagated to distant localities in the manner suggested, much might be learned by establishing twelve or fourteen similar instruments at an equal number of selected stations round the northern hemisphere. It is yet premature to indicate the class of instruments to be employed, but if their chief function is to record the time of arrival and the different phases of these wide-spreading movements, it is the writer's experience that many difficulties may be avoided in installation, adjustment and management, by using a type that is not too sensitive to extremely minute changes of level, such as accompany fluctuations in temperature and changes in atmospheric conditions. All of them should admit of adjustment to a similar degree of sensibility, and so far as possible be attached to similar foundations in localities or places where the effects of tremor storms, which often eclipse the effects due to earthquakes, are not likely to be pronounced. Photographic surfaces on which records are received, should move at a rate of *not less* than two inches per hour, which will enable an observer to determine time intervals to within 30 seconds.

It would seem advisable that the first attempt to make a seismic survey of the world should be tentative. Having ob-

tained the co-operation of observers in selected localities, each of these should be furnished with a similar instrument, and if possible receive personal instruction as to its installation and working. If this is done, then an inexpensive type of apparatus may be employed, which in an ordinary foundation will yield results not much inferior to those obtained from more elaborate arrangements, which subsequently it may be thought desirable to establish.

Although it may only be possible to minimise the effects of tremors, the records of these over extended areas may perhaps present new features. Other movements which are likely to be noted, but which will not influence the recording of movements resulting from distant earthquakes, will be diurnal and other periodic displacements of the pendulums. The records of these, together with those of local earthquakes, could hardly fail in adding to the knowledge we possess about earth movements.

The principal object of the proposal made in the foregoing remarks, is to determine the velocity with which earthquake motion is propagated over the surface of the earth, and possibly through its interior. If it is established that vibratory motion is transmitted with a measurable velocity *through* the earth, it will be difficult to over-estimate the value of the knowledge we shall have gained. The rigid scrutiny of the records bearing on this latter point have to be left to European observers.

At present the writer is engaged in drawing up a report upon the state of our knowledge respecting the velocity with which earth vibrations and waves are transmitted through rock and earth, and in making experiments to determine a form of simple instrument which shall be not only sensible to slight changes of level, but which is also capable of recording vibrations of small amplitude.

Since writing the foregoing, which was printed for circulation amongst a few of my friends interested in this branch of earth physics, I have received NATURE of December 27, 1894, in which, on p. 208, Dr. E. von Rebeur-Paschwitz gives a description of the remarkable disturbance of June 3, 1893, to which I have already briefly referred. In July of that year I sent photographs of this record to various acquaintances in Europe. One of these, together with a description of the same, because it was illustrative of a great number of unfelt earthquakes which I had recorded, was sent with the fourteenth report to the British Association on seismological work in Japan during 1893–1894. This report is, I believe, now in the press. The object in calling attention to this matter is to show that this disturbance, wherever it originated, was also pronounced at places far distant from Strassburg, Nicolaiew and Birmingham.

Mr. C. Davison, who writes the introduction to the description of the European records of this earthquake, makes a brief reference to the desirability of having a few well-chosen stations in various parts of the world where earth pulsations might be recorded—a matter on which I have had considerable correspondence with my friend Dr. E. von Rebeur-Paschwitz. At present Mr. Davison considers that Europe is fairly well provided with instruments. Instruments are certainly fairly numerous, but at the same time in many instances they vary in their sensibilities and also in their objects. Judging from the report of the Committee on Earth Tremors to the British Association in 1893, p. 294, it would seem that the instruments in Birmingham and Edinburgh are arranged to be unaffected by rapid tremors, and register "slow earth tilts only," while the tromometers of Italy are, I presume, constructed to record what this name implies. Whether they are able to record "elastic" tremors is a debatable matter. A very good illustration of what the heterogeneity of the instruments at present employed in Europe leads to, is given by Mr. Davison in the records of two earthquakes, contained in the report of the above-mentioned Committee for 1894, which may have had velocities of propagation varying between 1 and 12 km. per second, according to the type of instrument from which records were obtained. The apparent explanation of these anomalies is that different instruments have recorded different phases of motion, and for this reason I have been led to say that it is not likely that our present knowledge will be increased until there is greater uniformity in the methods of observation.

Mr. Davison's remark that "in Japan Prof. Milne's tromometer (as described in British Association Report, 1892, pp. 207–209) leaves little to be desired," requires qualification. As a "tremor" recorder it is excellent, but even as such I have improved it by reducing its length to 30 mm. and its total weight to 0·39 grms. Unfortunately however, because it is a tremor recorder, its movements are such that even on a photographic film only one metre distant, it may during a severe "tremor storm" give a trace which appears as a band two inches in breadth, which eclipses any effects due to distant earthquakes, for the recording of which it is therefore useless. At various times I have experimented with at least a dozen of such contrivances, which from the nature of their construction have necessarily short periods of vibration, and are therefore not sensible to slight tilting. Although I condemn these instruments for the recording of distant earthquakes, I must admit that I am indebted to a pair of them for having first made visible to me the diurnal wave.

In the *Seismological Journal*, vol. iii. p. 60, a sketch is given of a horizontal pendulum, such as I have used to record the daily wave and unfelt earthquakes since November 1893. One of these, which has a boom 5 feet in length, has usually a period of about 50 or 55 seconds. Altogether I have six sets of such apparatus with photographic recording surfaces, together with one or two others, which are read once per day.

These have been installed at and given records from eighteen localities—in caves, in the solid rock, in an underground chamber, and on substantial columns rising from the natural soil.

Although these instruments are exceedingly bad forms for tromometers, by these experiments—each of which continued over several months, during which time continuous records were obtained—much was learned about the localities where "tremor" effects might be avoided.

To solve the problem under consideration it does not seem necessary to have an instrument sensible to less tilting than 1″, and it is certainly undesirable to have one sensible to the phenomena called earth tremors or microseismic disturbances, which appear to have the character of earth pulsations. What is required is an instrument which is susceptible to the tilting produced by the undulatory slow travelling quasi-elastic disturbances of an earthquake, and at the same time is sensible to the minute, and possibly truly elastic vibrations which, both in Japan and Europe, outrace the more pronounced movements. The first object, and to some extent the second, is certainly attained by many instruments in Europe. From the records given by the long pendulum of Dr. Agamennone, of which I have not had an opportunity to see a full description or drawings, I take it that for the preliminary vibrations, the pendulum acts as a steady point, relatively to which the movements are magnified by means of a pointer arranged like that of a seismograph. The larger movements, which have periods of about 16 seconds, may be due to the slow heeling over of the pendulum following the motion of the supporting tower. About these latter movements we already know a great deal, and their velocities of propagation, as determined by the most accurate methods in Japan, do not materially differ from the rate at which the same disturbances continue on their journey to Europe.

What we most require is an investigation of the velocities of propagation of the elastic movements which apparently go from Japan to Europe in 15 or 20 minutes.

If such phenomena exist, and if the European records are correct, their existence is a reality, the instruments to record their repetition must be sensible to small but rapid vibrations; and for the results to be comparable, these instruments must not only be similar in construction, but they must be similarly adjusted and similarly installed.

Within a few days the writer will have completed two instruments differing only in their size, which may be described as conical pendulum seismographs in which the multiplication relatively to their centres of oscillation will be adjustable from about 20 to 40. The registration will as usual be photographic. It is hoped that because the multiplication is large, and because everything is as light as possible, the preliminary tremors (elastic vibrations) may be recorded; while because the booms are long, it is not unlikely that the sensitiveness to tilting will be sufficient to record the slower waves. They will be tested upon a foundation the diurnal tilting of which is known, and where it is also known that tremors (earth pulsations) are seldom met with.

JOHN MILNE.