ON A NEW SEISMOMETER.

BY DR. G. WAGENER, KIOTO, JAPAN: JUNE 1880. WITH A SUMMARY OF OBSERVATIONS BY E. KNIPPING.

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This new seismometer having been in practical use since November 1878, and the observations showing apparently reliable and satisfactory results, it now seems opportune to give a full description of this instrument.—Several seismometrical contrivances set up in Japan, in conformity with Robert Mallet's instructions in the *Manual of Scientific Enquiry*, London, 1871, or those contained in the *Anleitung zu wissenschaftlichen Beobachtungen auf Reisen*, Berlin 1875, having given no satisfaction (see Mr. Knipping's paper in the 14th vol. of the *Mittheilungen der deutschen Gesellschaft fuer Ostasien*, April 1878), it was intended to make an instrument suitable not only to mark the time of an isolated earthquake shock, or of each one of a succession of shocks, but also, if possible, to give some information more approximate and more complete than that which until now had been obtained with instruments intended to measure the extent of the motion of the earth. The principle was explained in a paper read in June 1878, and published in August 1878, by the above named *Deutsche Gesellschaft etc.* in Tokio, who decided to have the instrument made at the expense of the Society. Mr. Knipping undertook to superintend the manufacturing of the apparatus and to make the observations.

Like several other instruments, this new seismometer is composed in one part of a suspended pendulum; and it will be necessary to explain how it differs from the other instruments in principle and in shape, these explanations being sustained and completed by an experience of nearly two years.

Robert Mallet, in his 4th Report, British Association 1858, describes as the "oldest, probably, of seismometers" a pendulum, free to move in any direction" with a stile below the bob and a concave dish placed underneath, covered with a stratum of fine dry sand. "It was supposed, he says, that the stile would mark a right line when seen in a plane vertical to the sand-bed, and in the direction of the shock." Then Mallet describes several other seismometers and finally exposes his views on pendula in general, which, he says, "have disadvantages both theoretical and practical or constructive which render their indications inaccurate." In order to account for this latter draw back, Mallet explains the well known principle, that a pendulum can easily be made to swing by giving to the point of suspension, impulses in intervals corresponding to the time of oscillation of the pendulum or to a multiple of it; and that on the contrary the pendulum remains sensibly stationary when this is not the case. From this he concludes that the indication of the instrument will either be in excess of the horizontal component of the wave, or much less than it; but he does not propose that the oscillations of a pendulum should altogether be rejected as a means for indication in the case of an earthquake. Writing thirteen years afterwards (see Chapter on Seismology, in the *Manual of Scientific Enquiry*, 4th edition, London, 1871, page 311), Robert Mallet only recommends one solid pendulum which "by the shock, is caused to oscillate in any direction." In the whole of his 4th report, 1858, there appears to be not one single passage in which Mallet, who is plain enough on every thing, refers to an apparatus composed of a suspended weight and a suitable indicator to move against this weight in the moment it is still inert. But, of course, he is well aware, that a pendulum remains behind in the first moment of a shock, and knows also, under which conditions it will swing or not swing.—In later years, (see Le Conte's *Geology*, New York, 1878), Prof. Cavalleri appears to have proposed an instrument, which, according to the description, is nothing else—however with a slight modification—but a new edition of what Mallet calls the "oldest, probably, of seismometers." But it is said in the description, that the "pendulum tends to retain its position." Whether for the sake of this theoretical supposition, which is scarcely different from Mallet's statement that the "pendulum remains behind in the first moment," and his other explanations, Cavalleri's instrument has been free of all the disadvantages, which, according to Mallet, are common to all pendula, I do not know, nor have I been able to ascertain what sort of observations have been made with it. From 1877 to 1878, Mr. Verbeck in Tokio, not being satisfied with the results obtained through an oscillating pendulum, as he wrote himself to the author of this paper, put up another instrument composed of a heavy planed piece of wood with a slightly ballasted pencil in the middle, and resting through four crystal balls upon a polished marble slab. The piece of wood remaining inert during the shock, the pencil made certain marks upon a sheet of paper placed underneath. These marks are only very short strokes, and may well be considered as some more evidences of what results from Mr. Knipping's observations with the new seismometer, viz.: that the extent of motion of the earth, during an average shock, amounts to a few millimeters only.

Robert Mallet has pointed out a great many disadvantages or difficulties connected with pendula. If in spite of these objections, a new trial was made with a pendulum, it was for the reason, that, in case most of the drawbacks could be overcome, such an apparatus would have the great advantage of extreme simplicity. I may state at once, that the observations of nearly two years furnish sufficient evidence that the experiment has been successful to a very great extent. But before giving a full description of the new instrument, a few theoretical remarks will not be out of place.

If the point of suspension of a pendulum being at rest, receives an impulse, the bob of the pendulum remains behind in the first moment. It is this inertia of the first moment which the new instrument makes use of for indication. This remaining behind in the first moment takes place in all cases, whether the pendulum is long or short, whether it depends from a rigid or from a shaky scaffolding. Thus, a suitable indicator moving against the inert bob, is always sure to mark the *exact time* of the *first* shock. If the pendulum is not too short, so as to be dragged along before the end of the first impulse, the indicator will also allow to calculate from the indication the *extent of the horizontal motion; but only if we are certain that any following oscillations of the pendulum will not alter this first indication.* This already involves a considerable difficulty, chiefly if there is no registering apparatus, like the phonograph, which might render it possible to distinguish the tracing of a shock from the tracing of the oscillations of the pendulum. In general, it is easily understood, that the indication of nothing but one first impulse during an earthquake does not involve very great difficulties. But they are considerable, as soon as the problem is to mark all the different impulses during an earthquake with equal correctness. The most perfect seismometer would be obtained, if a body could be made permamently inert during an earthquake; but this being an ideal, we most likely must be content with a body, which at each new shock, is *likely* to be in the same condition as when at rest.

To examine whether this is possible or not, we have to minutely consider how a pendulum is influenced by the various forms of an earthquake and the phenomena depending on it. The well known principle as above mentioned, shows that it is not advisable to use a long pendulum pending from the roof of a house or any other point subject to vaccillations in consequence of the shock. These being slow and not isochronous, they are most likely and even certain to affect a pendulum, whatever may be its length. The principle also makes it evident that, the point of suspension being upon a rigid scaffolding not liable to vacillations, it is sufficient to give the pendulum a certain length in order to be almost sure that it will not be affected by eventual periodic oscillations of the soil which always will be quicker than the time of oscillation of the pendulum. Indeed, it can be shown with a very simple apparatus composed of a horizontal bar of wood, with a slit in the middle to permit a string to pass through, one end of which is fastened to a block of wood, the other end carrying a weight—that the point of suspension can be moved to and fro, in excursions of several inches, without producing any noticeable swinging of the weight. These were the ideas explained in the paper of June 1878, and it was only said (see page 221 and page 223) that nevertheless the indications might be obscured by oscillations, but that it was superfluous to describe improvements before having seen that there really were such oscillations; that in general it was to be seen, how the instruments would work, that even a failure would teach something, and that there was no other way of information but the experiment. Its particular construction had only a general purpose to prevent disturbing oscillations, and the first record published in May 1879 stated that it had worked to entire satisfaction. But the reason of its good working and the difficulties of pendulum seismometers in general can be better explained now, after an experience of nearly two years and after having heard of other pendula having been swinging, than this has been done in the first paper.

The above principle referring to the influence of periodic impulses upon a pendulum, takes into account no other element but a periodic and constant interval of time between two successive impulses, and involves—for the case that no swinging shall take place—the supposition that the effect produced in one direction is equal to that in the opposite direction. With the above described pendulum apparatus, it can easily be shown that, if the point of suspension is moved to and fro with equal excursions on both sides of the starting point, the pendulum does not swing, even in spite of considerable excursions. The same—or only a very slight swinging—takes also place when the excursions decrease very gradually on both sides of the point of rest, until the point of suspension is brought to rest again. But we can not suppose that at the time of an earthquake, the earth oscillates with such regularity. In the *Anleitungen zu wissenschaftlichen Beobachtungen auf Reisen*, Berlin 1875, page 311, K. von Seebach says: "Only during very weak earthquakes, the wave-like motion appears as a uniform tremor; the general case is that in this motion one or several more violent oscillations can be distinguished, which are then designated as separate shocks."—Anybody who ever has made the experience of an earthquake, will agree with this view of its features. If we now repeat the pendulum experiment under conditions similar to this description of an earthquake, we will find that the pendulum is easily made to swing. With a bodily mass so discontinuous and heterogeneous, and of so little elasticity as the soil, we may even admit, that at the time of a shock every particle of the soil is thrown out of its position of rest, but that in coming back it very little depasses this former position, and comes to rest again after a few rapidly vanishing oscillations, differring in this entirely from the different points of a highly elastic body. It happens thus that the effect of the first impulse, that which we call the shock, by far dominates the effect of the following oscillations. We therefore may compare the total of the effect to that produced by a sudden motion forwards and then backwards to the point of rest. If we make this experiment with the point of suspension of a pendulum, the latter only receives the impulse at the forward motion, but no impulse when the point of suspension comes back to its former position. The consequence is that the pendulum will swing, more or less, the degree of swinging depending on the extent and velocity of the shock, on the length and the weight of the pendulum, and on some minor circumstances.

This particular feature of an earthquake, that is some more or less of oscillations of the soil intermixed with sudden and much stronger shocks, being the usual case, it is clear, from the above explanations, that the principle of the influence of regular periodic oscillations of the point of suspension upon a pendulum is, after all, only of minor importance. It has been said (see *Japan Gazette*, May 1st) that "it is a well known principle that the bob of a long pendulum may be assumed to be sensibly stationary during most shocks, since the periodic time of a shock is probably far less than the natural period of oscillation of the pendulum," and further that the "pendulum method is widely trusted by seismologists." It is not said what method or what instruments are meant; but it can be safely asserted that the said principle alone does not involve the most important feature of an earthquake, and well may "grave doubts" be expressed (see same place) as to the "supposed steady pendulum really being steady." However it seems, as will be shown, quite possible, that some pendulum method is sufficiently trustworthy for time and approximate intensity. And there is no other means to be tolerably sure of this but a connected series of observations or a registering apparatus.

It will have been understood from the above explanations that, if the earthquake consisted in regular or nearly regular and isochronous, only gradually decreasing oscillations of the soil, the construction of a seismometer would present no difficulties whatever, after once having adopted the principle to make use of the inertia of a pendulum instead of the oscillations. But in order to make a practical instrument, it is also necessary to render the indications unaffected by pendulum oscillations after a shock, even in the case that several shocks should follow one another at short intervals. This appears to be realised by the seismometer to be described hereafter; and I think that in presence of the facts and evidences gathered after an experience of nearly two years with the same unaltered instrument, it is not too much to give of this apparatus the following definition:—

The new seismometer makes use, for the indication of time, horizontal intensity and direction, of the perfectly certain—under all conditions perfectly certain inertia of a pendulum in the first moment. All these indications—even in the absence of a moving registering apparatus, the indications of intensity and direction being those of the most violent shock during an earth-

quake—are not altered by the pendulum oscillating in consequence of an impulse, whatever may have been the violence of this shock. And further, if the pendulum does oscillate, it comes to rest again after a few seconds, even if the shock has been as severe as the most violent shock that has been experienced in Tokio in later years, so that the instrument is almost certain to indicate every single shock of an earthquake under the same conditions of rest as the first one.

The correct and distinct indication of the time of each shock is undoubtedly the most important query of seismology. All seismologists agree in this, and amongst observers in Japan, I may mention Mr. Knipping, who began his observations in 1874 with different instruments suggested by Robert Mallet and others. In his paper on earthquakes in Japan (see Vol. 14 of the *Mittheilungen der deutschen Gesellschaft etc.* April 1878, page 118), he says: "The final result "of the experience acquired in Tokio with the above said "seismometers, has been so unsatisfactory that they must "be entirely rejected, even in countries subject to tolerably "strong earthquakes. Indications of time, as exact as pos-"sible, in places connected by telegraphic lines, as K. von "Seebach has proposed them showing also their application "to determining several elements of the earthquake-wave, "seem to be the only right thing to get."

In his report on the Meteorology of Tokio, for 1879, page 42, Professor Mendenhall says: "I regard it as highly "desirable to erect some simple indicator, which may not be "liable to get out of order, and which in connection with "some of the time-cylinders in use, or to be used in the "observatory, may indicate the time of the shock, certainly "or with the smallest chance of failure. If we shall succeed "in this one determination with unfailing certainty, the "result will be a contribution of no small value and well "worth the trouble and expense which will be rendered "necessary."

It was Mr. Knipping's paper, that induced me to try the construction of some more practical instrument than those which, in his opinion, had proved a complete failure.

Only I gave a little more extension to the problem, explaining that for several reasons, besides the absolutely indispensible element of time, it would also be desirable to have an indication of intensity of more approximate correctness than hitherto had been obtained with seismometers. The different instruments for time, intensity and direction, as well as the object of a moving registering apparatus were described in vol. 15 of the Transactions of the German Asiatic Society, August 1878. Since the first object was to be quite sure of the good working of the various instruments, it was decided to dispense for a time with the registering apparatus which has been ordered only a few months ago and is not quite ready yet. The apparatus for time and horizontal intensity is at work since Nov. 1878, and apparently in so satisfactory a manner that there were no reasons for making alterations. It is the same which was sketched and described in the paper published in August 1878, with the sole difference that the indicating pendulum rests upon a sphere instead of a point as was said in the description. Experiments have shown that, in putting this apparatus into the position which it must have had at the end of the strong shock of December 3rd, 1879, and abandoning it to itself, it comes to complete rest again in not quite four seconds. During the earthquake of February 1880, the thread leading to the index-wheel was broken, but for some accident, it could be assumed with good probability that the extent of the motion of the soil had been five times as much as in December 1879. Giving the apparatus the position corresponding to this assumption, it comes to rest in 15 seconds. In these experiments, without an earthquake, the apparatus, as will be understood by the description, is in a condition much more favourable to oscillations than in the case of an earthquake. We therefore may fairly assume that after a strong shock, the apparatus is again at rest in a much shorter time. It must be observed that the construction of the apparatus allows to still reduce these figures; but it is quite unnecessary to do so before the registering apparatus is ready. However, they are sufficient to make it plain that in most cases, when several shocks can be noticed in one earthquake, the apparatus will indicate every one of them, starting from the same condition of rest as when the first shock occurred.

As to intensity, I also shall refer to facts in order to show that the indication of the extent of motion of the earth, at the time of a shock, has never been altered—or not sensibly altered—by the following oscillations of the pendulum Before evidencing this by figures, it must be observed that the indications of intensity are not figures eliminated as to say out of a sinuous line traced upon a revolving registering apparatus, but are figures directly and distinctly shown by the index. From November 1878 until December 1879, 24 earthquake-shocks have been indicated: and the different values of the extent of motion, the instrument always indicating that of the most violent shock during an earthquake, are comprised between 0^{mm} ($0{,}03^{mm}$ were actually indicated) and $4{,}3^{mm}$. These figures are sufficient to show that eventual oscillations of the pendulum can only have had a very small, quite insignificant influence, or more likely none at all. Thus the above figures resulting from the indication in the first moment when the pendulum is still at rest, must be considered as very approximately correct. They also corroborate the other statement, that the oscillations, being only of a very small excursion, come to rest very soon. The reason why the new seismometer is so little or rather not at all put into motion by the impulse of an earthquake-shock, will be fully explained in giving the description of the instrument. The apparatus for determining the azimuth of the strongest shock being of the same construction as the other one, the above statement referring to the almost complete absence of disturbing oscillations, applies also to this instrument.

It has been said that the registering apparatus, indicating the time and intensity of each separate shock during an earthquake, is not ready yet; and it may also be observed that its construction has been reduced to the utmost simplicity, because the main object was to first test the working of the whole system before ordering a more expensive instrument. In the shape which is intended, it will show whether some more improvements referring to the steadiness of the weight are necessary or not and there is still a large margin left for improvements. They will be easy enough, and in case of need, the point suspension of the pendulum will be arranged in such a way as to remain behind like the bob itself, and to retake its position after a few vibrations which in no way or scarcely can affect the suspended weight, provided only they are quicker than the time of oscillation of the pendulum.

To determine the azimuths of all the different shocks during an earthquake, is not without importance since it may happen, that for some deflection of the wave, or because there are more than one centre, they are not all in the same direction. Such an apparatus will be made after having finished the time registering instrument.

The vertical intensity of a shock is measured through a buoy suspended in water and forming the inert body. It is very likely that a similar arrangement has already been proposed by other people.

Amongst all the instruments to be described hereafter, the most important one undoubtedly is that for time and intensity; and we may be allowed to point out some of its advantages:

It is sufficiently sensitive, but also solid enough to resist strong shocks without getting out of order;

The connection between the weight and the indicator is permanent, and consequently independent of the observer's carelessness or attention;

The indication of intensity is in no case sensibly altered by following oscillations of the pendulum;

After a shock, even a very violent shock, the apparatus comes back to complete rest within a few seconds;

The instrument is plainly comprehensible to any body, and avoids electric or other arrangements which it would require a certain scientific training to keep in order;

The instrument is not expensive;

It is transportable and requires only a very small space any where under a shelter.

Finally after all these explanations, the reader is referred to the summary of observations (see hereafter) made by Mr. Knipping, to whom the writer of this paper is extremely indebted for the untiring perseverance, he has so kindly given proofs of, in superintending the construction of the instruments and in making the observations. The results undoubtedly have a most satisfactory appearance; and the task will now be to ascertain the practical limit of perfection which can be attained.

DESCRIPTION OF THE APPARATUS FOR TIME AND HORIZONTAL INTENSITY.

The scaffolding is in the shape of a four-sided pyramid solidly framed and put upon the ground, in such a way that it is bound to follow its motion. From this scaffolding, an iron ball weighing 40 to 50 lbs., is suspended by a thick bundle of untwisted silk-threads 3 feet long. At this same scaffolding, underneath the heavy weight, is fixed a solid iron bar carrying the indicating part of the instrument This consists of a stiff pendulum, suspended by a point below its upper end. The suspension must be such that by the slightest as well as by the most violent shocks or excursions of the soil the pendulum should be carried forwards and backwards with equal sensitiveness and without getting out of order. For this purpose the support of the pendulum is a metallic sphere of $\frac{2}{3}$ of an inch diameter, and the pendulum rests upon this sphere with a smooth plate forming the top of a hollow cylinder. The inner diameter of this cylinder is exactly equal to the diameter of the sphere so that the pendulum can pivot in all directions upon this sphere, but can not slide. The lower and longer part of the pendulum is fixed at this cylinder through a large vertical brass ring, which allows the iron bar carrying the sphere, to reach underneath the point of suspension. This brass ring does in no way effect the pivoting of the pendulum, since in case the ring should hit against the iron arm, the apparatus will only give a slight turn on its geometrical longitudinal axis, and continue to pivot. The connection between this pendulum and the heavy weight is established in the same way as the suspension itself. The iron ball forming the weight carries below, a small sphere like the supporting point, and this sphere fits exactly into a hollow cylinder, screwed on the top of the indicating pendulum. It will be easily understood that through this connection, as soon as the supporting point of the indicating pendulum makes the slightest horizontal movement the heavy weight remaining motionless, the indicator is bound to pivot, forwards and backwards, once or repeatedly, exactly as the motion of the point of suspension requires. It is advisable or even necessary to give to the indicating pendulum such a construction, that its centre of gravity is near the point of suspension. This at least was aimed at in the construction of the instrument, which has given, since Nov. 1878, entire satisfaction as to its working qualities. It is evident also that this pendulum must be as light as possible in order not to affect the heavy weight; but it is also evident that this short pendulum has a much shorter time of oscillation than the former one, and that its very weak impulses take place in alternate directions. It is therefore certain that in case oscillations *should* occur, which will always be after the first pivoting, they cannot affect the *indications* of the pendulum. In this first seismometer, since nothing was known concerning the real excursion of the soil during an earthquake, it was considered advisable to make the pendulum long enough to get clearly visible indications and to stop a clock even in cases of very weak shocks. The length of the pendulum from the point of suspension to the lower end is 2 feet, and to the upper end or rather to the center of the small sphere which holds the upper end, is 1 inch. Thus the ratio of the two arms of this vertical lever, is as 24 to 1. A scarcely perceptible motion of the point of suspension produces a considerable motion of the lower end. At this lower end is fastened a flexible silk-thread, which passes through the small hole of a thin porcelain plate immediately underneath. This thread is wound around a light

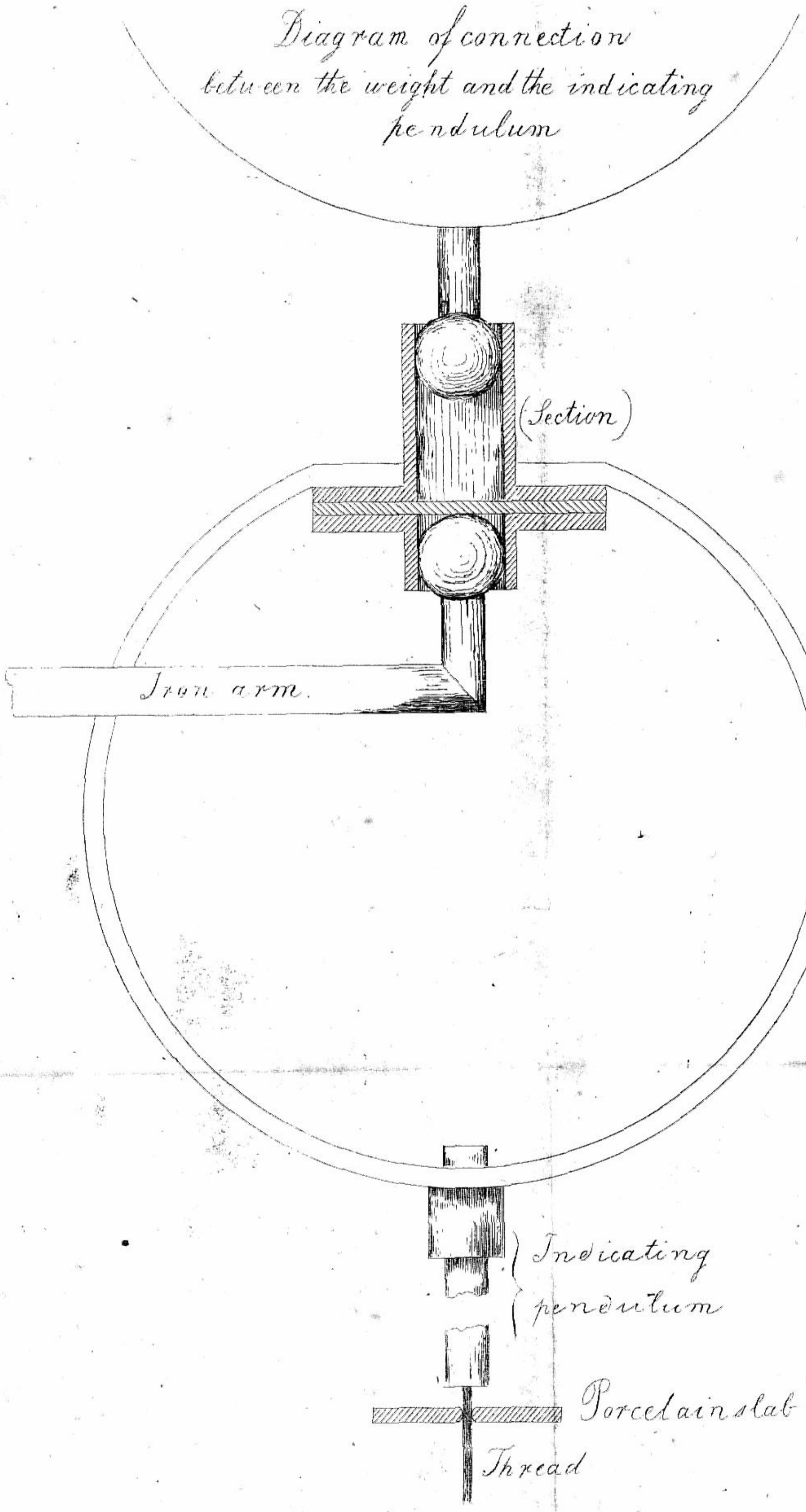
Diagram of connection
between the weight and the indicating
pendulum
(Section)
Iron arm.
Indicating
pendulum
Porcelain slab
Thread

wheel with an indicating needle, and is also in connection with a lever which by falling down, stops a clock. It is clear that as soon as a shock occurs, the pendulum pivots, and whatever may be the direction of this pivoting, pulls the thread through the hole; by this one movement the clock is stopped, and the indicating needle is turned more or less showing the intensity of the shock. The real extent of excursion is then easily calculated. It will be noticed that the connection between the indicating pendulum and the heavy weight, after the shock, is exactly the same as before, and that nothing has to be done but to put the needle and the clock-lever back to their former places.

It now has to be shown how this arrangement is fit to check the effect of one impulse upon the heavy weight. Experiments with our little pendulum apparatus (see above) have shown that the weight sensibly remains behind till the end of the shock. In this apparatus, it is the more so the case because the bundle of silk-threads being elastic longitudinally as well as transversally, yields to the pull before, it acts upon the weight itself. During this first impulse the two points of suspension of the weight and of the indicating pendulum both have moved forwards. Consequently the two longitudinal axis of both pendula, at the end of the earth's motion, form an obtuse angle whose vertex is towards the direction from where the shock came. In the moment where the forwards motion of the earth is finished, the indicating pendulum having acquired a certain velocity does not stop at once, but tends to continue its motion through its inertia. However its point of suspension being now momentarily at rest, this forward motion can only take place by pressing against the heavy weight in a direction opposite to the impulse. The consequence is that the *inertia of the indicating pendulum in motion checks the tendency of the weight, at rest, to move forwards in consequence of the received impulse.* And it is self-evident that this counter action of the indicating pendulum is in exact proportion to the violence of the shock. It happens thus that at the end of the shock, both pendula have a moment of perfect rest with no tendency to move in any direction. The now following motion only is due to the circumstance of their being out of their position of equilibrium, and depends on gravitation alone. But as the large pendulum begins to swing, its point of suspension come back to meet its motion; besides, it has the impediment of the indicating pendulum, which remains always connected with the large one. The result is that both pendula exercise such a reaction one upon the other, that the swinging can not reach far enough to alter the indication of the first moment. The hitherto explained checking action of the indicating pendulum can be regulated to satisfaction with the help of a small sliding weight.

APPARATUS FOR DIRECTION.

Like the first apparatus, it consists of the heavy weight and a pendulum of identical construction. But this latter carries at the height of the point of suspension, eight light horizontal arms, 9 inches long, connected with each other at their ends through a light hoop. Above this hoop and upon a sort a platform, are eight wheels like that in the former apparatus, with indicating needles. A thread would around each of these wheels is connected with the end of the corresponding arm of the pendulum, and in such a way, that, when all is at rest, all these threads are tense and the needles upon zero. When a shock accurs, the indicator will pivot, the plan of the eight arms will be inclined, some of the threads will be pulled, and the needles turned more or less. The wheels are put up so as to force the eight arms into the eight principal directions of the compass, and to keep them there. That point where the greatest pull took place, shows the direction from where the earthquake came; and this indication is *not* affected by slight balancing motions of the eight arms, which may occur because it is not possible to give to the instrument a mathematical precision. When it has to be put in order again, nothing is necessary but to bring the needles back to zero; and as there may be slight changes in the tension of the threads, and the needles not come back exactly to zero, the graduated circles are made moveable so that the needles can always be turned upon zero.—I dare say, that although this apparatus looks a little complicated on account of the eight wheels, its working can easily be understood by anybody.

If the seismologists will be content with the exact azimuth of the first shock only, it is easy enough to connect the eight arms with the threads in such a way, that in the moment of a shock, all the threads in the raising half of the disk are disconnected, whereas on the dipping half they remain tight. But as soon as this half begins to go up again, they are also disconnected. The consequence is that the needles on the side from where the shock came, remain exactly in the position they had at the end of the shock, whereas upon the opposite half they all remain upon zero. No oscillations of the large pendulum can alter this perfectly correct indication.

Registering apparatus.

Like in the drums used as phonographs, one end of its axis is not a cylinder but a screw, so that each point of the drum when it turns, describes a screw line. A pencil remaining motionless would then mark a screw line upon this drum, or if the pencil moves up and down, it will draw a sinuous line, the sinuousities of which will not fall together. This drum is turned directly by one spiral spring whose axis lyes in the prolongation of the axis of the drum. Since the latter is forced to ascend, no further regulation of the movement is necessary; it will become uniform after a very short time, and if not, it does not matter as will be seen hereafter. When the spring is wound up, the drum is prevented from turning, by a sort of catch. In the moment an earthquake shock occurs, the thread at the end of the indicating pendulum (see former descriptions) pulls a light lever, the catch drops and the drum begins to turn. In order to prevent the short delay resulting from the inertia of the drum, the catch is constructed in such a way, that it helps to start the drum. The same thread pulls a pencil, which, through a combination of two levers with a link well known in mechanics, is forced to make only a rectilinear motion up and down. The arrangement is made in such a way, that the starting of the drum and the pulling of the pencil through one and the same thread, don't interfere at all with each other. The drum stops by itself after a few revolutions, which may last four or five minutes. The observer, when all is finished, takes the time in the following way. He brings the drum back to its normal position stopping it with the catch. He takes in one hand his pocket watch and in the other the thread of the pendulum. Pulling it now at regular intervals of say 5 seconds, he will start the drum, which will turn exactly as it did before, and the pencil will mark intervals in space corresponding to the regular intervals of time. Provided the drum only turns in the same way as before—and there is no reason to suppose a perceptible difference—it is indifferent whether the drum has had a perfectly uniform motion or not. It would be easy to find the perfectly correct time through interpolation. Now, since an other apparatus has given the moment of the first shock, the diagram of the drum will show the excursion, the moment and the duration of each successive shocks. Any secondary oscillations of the pendulum will most likely be immediately recognised, since their shape can easily be determined through experiment without any earthquake. I may finally add that, in order to help the alternate motion of the pencil, for which its own weight and the weight of the levers might be sufficient, it has been considered useful to fix the end of the thread at a spring, which pulls it down again.

Apparatus for vertical intensity.

This instrument consists of a sort of buoy suspended at a lever, whose fulcrum is rigidly connected with a tub to be filled with water. The lever is counterweighed in such a manner that the buoy, whose specific gravity is a little above one is suspended amidst water. If now the tub is suddenly raised by a vertical motion of the ground, the buoy will not follow immediately and remain behind just as the heavy weight in the other case. Thus it pulls the lever, and the end of this lever, making a very considerable excursion in relation to the ground and all the things rigidly connected with the ground, can pull a thread and move a needle like the thread of the indicating pendulum in the other instruments.—I may observe here that the buoy may be made as heavy as anybody thinks proper, since it will always be carried by the counterweight upon the lever. But in this case, by the sudden shock, the lever might be strained so as to be bent or broken or the connection with the tub might be damaged. For these and other merely practical reasons, the buoy was not made too heavy. Experience will show which are the best proportions.

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* SUMMARY OF OBSERVATIONS, MADE WITH DR. G. WAGENER'S SEISMOMETER, BY E. KNIPPING.

1. *Maximum horizontal motion of a point of the earth's surface, measured from its position when at rest, November 1878 to April 1880.*

Number of earthquakes.	Degrees shown by the instrument.	Corresponding maximum horizontal motion of the ground in millimeters.
10	0° to 5° . . .	0 to 0.15 mm.
7	5 ,, 21 . . .	0.15 ,, 0.5 ,,
8	21 ,, 114 . . .	0.5 ,, 2.5 ,,
2	114 ,, more . . .	2.5 ,, more ,,

The clock lever is pulled down whenever the instrument marks 3 degrees or more; *i.e.* when the motion of the ground amounts to somewhat more than a mere tremor or to more than 0.1 mm.; but this is not to be considered as the lowest limit, at which the clock can be stopped; in a new instrument there will be no difficulty in reducing the last figure to 0.03 or even less.

The extent of the motion as given by the indicator has always been in perfect accordance with the violence of the shock, as far as this can be estimated by the feeling.

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* For first summary see: *Mittheilungen der Deutschen Gesellschaft etc. Ostasiens,* vol. 17 May 1879; reprinted in *Wochenschrift fuer Astronomie etc.* edited by Dr. Klein, Cologne 1879 page 365 and *Zeitschrift der Oesterreichischen Gesellschaft fuer Meteorologie* Vienna March 1880.

The force, with which the indicator strikes against the weight in heavy earthquakes, or rather the inertia of this weight, may be judged from the fact, that February 22nd 1880, the thread fixed to the indicator, was broken, its length not being calculated for such heavy shocks.

2. *Maximum vertical motion.*

was observed since January 1879, 8 times, but only in 4 cases the angle indicated by this instrument amounted to 1 degree (0.02^{mm}. absolute measure) or more; the greatest value, observed until now, was 0.56^{mm}. February 22nd, this year.

3.—*Direction of shock.*

The instrument showing the direction, whence a shock came, through the dip of the plan, formed by 8 arms around the indicating pendulum, indicated upon the graduated circles (since May 1879.)

3 times	a maximum	angle	between	0	to	5	degrees.
5 „	„	„	„	5	„	100	„
3 „	„	„	„	100	„	more	„

The length of an arc of 5 degrees in this instrument is about 7^{mm}. and corresponds to a dip of the plan of 0.4 degrees.

As a sample of the kind of indications of this instrument I give here the figures in degrees for the 8 arms on Dec. 17th, 1879.

Arms	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.
Degrees	5	29	87	123	105	42	0	0

Whence the direction, from which the shock came is found as about S. 25° E.