ON THE APPLICATION OF PHOTOGRAPHY TO SEISMOLOGY AND VOLCANIC PHENOMENA.

By Prof. W. K. Burton.

There is scarcely a branch of art or science that does not at the present day call in the aid of photography, either directly or indirectly, and Seismology is no exception. It may, therefore, not be out of place in the case of a journal particularly devoted to this subject, to enumerate and briefly describe the various applications of photography that have actually been made, or that are suggested, in connection with earthquake and volcanic phenomena.

First, of course, we have the common application of photography to record the effects of earthquakes and of volcanic eruptions. The value of photographs of this kind cannot be over-estimated, but it will not be fully appreciated till considerable time has elapsed, and until future Seismologists want to compare the effects of earthquakes and eruptions of their time with those of the present time. We can imagine of what value they will become if we think what we would give for an accurate set of photographs of the effects of any historical earthquake or eruption, say of the last century. Undoubtedly, a hundred or two of years hence, it will be of the greatest importance to geologists to be able to compare the condition, for example, of Bandai-san with its condition within a few days of the eruption, that blew its upper half into the air nearly five years ago. The more rapid changes in the interior of the craters of active volcanoes can also thus be noted with advantage. Even such secular movements as the gradual rising or depression of coasts may also, perhaps, be recorded more definitely than they have been heretofore.

There is one thing that should be emphasized here, and that is the importance of preserving systematically all photographs of the kind mentioned, printed by some permanent process. In cases where the photograph is of such general interest that the outside public may be looked upon for the purchase of anything over about 50 copies, the collotype process is at the time of writing to be recommended, in other cases the platinotype, in spite of its present comparative expensiveness on account of the recent great rise in the price of platinum. Up to the present time, so far as the writer knows, such photographs as are of particular seismic interest are to be found scattered through various publications, but have not been systematically brought together in any single collection.

Prof. John Milne has used photography in determining the curvature of the sides of volcanoes.

That is to say the inclination and curvature were measured from photographs at the time in existence. In using photographs for this purpose it is necessary to be sure that the swing back of the camera was vertical at the time the photograph was taken, otherwise the measurements will not accord with the truth. Now, although photographers have been pretty well drilled into appreciating the necessity of having the swing back of the camera vertical in the case of buildings, there are few that appreciate the necessity in cases where the subject contains no right lines, and the greater number of photographers "tip" the camera without bringing the swing back to the vertical again, in photographing a high mountain. This is, indeed, one of the reasons for the commonly unsatisfactory rendering of mountains by photography. The effect of tipping back the camera, without readjusting the swing back, is to give an effect in the photograph, as if the mountain were leaning away from the camera to just the amount that the ground glass leans back. In other words the slope of the mountain is reduced, and the mountain is dwarfed. There may also be slight errors due to refraction.

We next come to another set of uses of photography that need little more than enumeration. Thus the record of an earthquake, by nearly every seismograph, is scratched on smoked glass, the smoke film being afterwards fixed with common photographic varnish. It goes without saying that photography is the best way of obtaining copies of such records. The blue process is most commonly used, although, in the case of the small diagrams given by bracket and duplex pendulum seismographs, more delicate processes have a decided advantage. Except for want of permanency, albuminized paper is to be preferred to anything else.

It scarcely needs to be stated that photography has been useful in producing illustrations of seismological instruments, also, in a number of matters of detail such, for example, as the production of scales, with finer division than any that were readily procurable machine divided.

We now come to a consideration of more special adaptations of photography to seismology, and, to avoid the necessity for repeating his name every few lines, I state here that nearly all these adaptations are the work of Prof. John Milne F.R.S., the writer sometimes giving assistance in some of the purely optical and photographic parts.

Some two years or so ago, an attempt was made to find whether any change in electrical potential between the earth and the atmosphere preceeded, accompanied, or followed earthquakes. An instrument to keep a continuous potential record was devised on the following lines. One terminal of a mirror galvanometer was connected with a metal plate in a well of considerable depth, the assumption being that the potential of the well water would be the same as that of the earth at the same depth. The other terminal was carried to a metal plate at the ground level. A beam of light was thrown on the galvanometer mirror and, being reflected, was received on a photographic plate, narrow and long, kept moving slowly in the direction of its length by clockwork, A continually changing potential was shown, and there were several cases in which there were decided deflections at the times of earthquakes, but there was not sufficient consistency in these to make it evident that they were the result of anything but the mechanical effect of the shocks on the galvanometer. The subject is one that yet requires attention.

There has been much investigation of "earth tremors" and "earth tilting." We are accustomed to look on the "solid earth," apart from its planetary motions, as the very type of what is stable and steady, but it is now known that it is never at rest. It is always trembling, and there is reason to believe that its surface is often slowly tilting in one direction or in another. These motions are extremely small; to get indications of them, much less to measure them, is very difficult, and, up to the present, it has been impossible to separate them, one from the other, with certainty. Thus no tremor recorder has yet been made of which it can be said with *certainty*, whether it is recording true tremors or "tips." An ordinary pendulum will be affected by "tilts" but not by tremors, unless these happen to coincide with its period. The difficulty is to record in any way the extremely small motion of the bob of the pendulum. A partly successful attempt was made to solve the difficulty by photography. A silver bead was suspended by a silk fibre in a hollow stone column, which prevented atmospheric influence. A beam of light was thrown on the bead, and the image of the point of light, passing through a micro-objective, placed vertically below the bead, gave an image of the spot of light on a plane at a considerable distance below it, along which a photographic plate could be made to travel by clock work, the motion of the bead being, of course, greatly multiplied,—being in fact multiplied in the ratio of the distance between the bead and optical centre of the lens* and the distance between the optical centre* of the lens and the plate receiving the image.

A word or two should be said on the optical principles here involved. If a silver bead were a perfect sphere, or indeed, if the surface were everywhere convex, the form only approximating to a sphere, the spot of light produced by the reflection of any source of light, say a lamp flame, could be made as small as might be desired, without being reduced in brightness. The further the source of light is moved away from such a bead, the smaller becomes the spot, but its brightness remains the same and is, indeed, at all distances, leaving air absorbtion out of the question, the same as the source of light itself, less a constant percentage of loss on account of absorbsion of light at the reflecting surface. This arrangement is, in fact, the "artificial star" used by opticians in testing telescopic and other objectives, when it is not convenient or possible to focus on an actual star.

It was thought that, in the case of this instrument, as the spot of light could be made indefinitely small, at will, the image of the spot could be made as small as might be desired, however great the amplification. It was found, in practice, that this was not the case. If the amplification were great enough to be useful, the spot of light was too large to draw anything but a very wide line. The lens was a high class ⅛ inch micro-objective, and the fault was probably not in it. It is likely that the bead was not really convex throughout, but that the surface consisted of minute facets, or more likely grooves. If a bead of mercury could by any means be used the results would probably be much better.

Excellent results have been got by the aid of photography

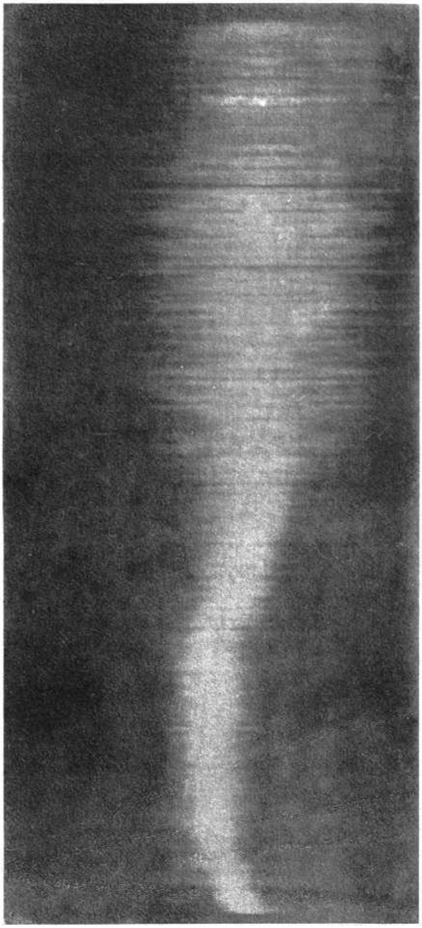
* More strictly one of the "principal points" of the lens.

by the tremor recorder described in a report on the Volcanic Phenomena of Japan. (British Association Reports 1892.)

The only difficulty here is that it cannot be known for certain, whether these instruments are showing tremors or "tips." In this case the light passing through a narrow vertical slit, behind which there is placed a small lamp, passes farther through an objective, is received on the mirror, and is from it reflected on to a horizontal slit in the front of a box which contains a photographic plate moving vertically by clockwork. Of course any motion of the mirror of the instrument, whether produced by tremors or "tips" is amplified by the beam of light, whilst the horizontal slit cuts off all superfluous light, so that a spot only reaches the plate. Daily observations were taken on plates 12 inches long, 2½ inches broad, moved by clockwork, at such a rate that they took 24 hours to travel their whole length. With this slow travelling vibrations were not separately registered. The breadth of the line across the plate, indicated the amplitude of the vibration at any particular time and showed that there attained a maximum at intervals five to ten minutes. In working with these slowspeeds it was found that the light of a small kerosene lamp was ample, if the plates were rapid, but it was considered advisable to get a record of the actual separate vibrations during "tremor storms." To do this the plate was caused to travel rapidly, at the rate of 12 inches in about 30 seconds. With this rapid travelling the light of a lamp was quite inadequate, and a magnesium light produced by the burning of magnesium ribbon was used. The annexed diagram illustrates the sort of records that were got on the slow travelling and on the quick travelling plates. Fig. 1, that showing the result on a slow travelling plate, is actual size, representing a part of the plate only. Fig. 2 showing the result on a quick travelling plate, is reduced to its present size from a length of 12 inches.

Of course the line of light that did the actual photographic

I.



2.

Fig. 1.—This is a half-size reproduction of tremors recorded on a quickly running plate. The chief points to be noticed are, first that the tremors increase and decrease in amplitude and that their period varies. May 28th, 1892.

Fig. 2—This is portion of a diagram in which $\frac{1}{2}$ inch equals 1 hour. It shows a deflection of the vertical, how tremors become large, and how maxima occur every 4 or 8 minutes. March 12th-13th, 1892.

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work was an image of the slit, which slit was made very narrow. I was surprised, in connection which this, to find how little difference it made what kind of objective was used to cast the image. A high class portrait objective was suggested, as on account of the perfect correction for both the spherical and chromatic aberration of the pencil's axial, or nearly so, I thought that the results would be much superior to those got with an inferior lens. To my surprise there was very little difference between the results got by the use of such a lens, and those got by the use of a single double-convex, or "crossed," lens, not even achromatized.

In 1887 MM. Fouqué and Michel Lévy described a set of experiments they had made to determine the rate of transmission of shqck of an earthquake nature, produced by exploding dynamite, and in other ways, through different kinds of soil, using a photographic arrangement for recording the time and durations of vibrations. An incandesent electric lamp threw a beam of light at an angle through a lens and on to the face of mercury in a dish. The reflected beam of light was brought to focus on a revolving plate. If there were no motion, of course the light simply drew a circle. If there were any vibration, the beam of light was set in motion, and the circumference line of the circle was widened, and became indistinct. Thus the beginning, duration, and ending of the motion were indicated.

So much for what has already been done. It may be worth the necessary space to say a word or two about applications of photography that are, as yet, only contemplated.

In the case of all seismographs at present in use the "steady point" is a comparatively heavy mass of metal. There are no objections to this in the case of slight earthquakes but, in the case of great ones, when we have tilting the mass is liable to over-swing the mark and to exaggerate the motion. There is also the objection that it is never known for certain whether "tips" or lateral motions are being registered. It is possible that this difficulty may be got over by the use of a very light "steady point" but, in such a case the ordinary method of drawing the record by a point scratching through a smoked film on glass, will not be admissable, as the friction would be too great. It will be necessary, in this case, to resort to photography, which introduces no friction at all.

At places where no regular seisological observatories are situated it is often desirable to have a record of the time of occurence of earthquake. The simplest way of doing this automatically is to have an arrangement whereby a clock is brought to a stop at the moment an earthquake begins. One objection to this arangament is that thus stopping a clock makes it often difficient for observers to reset it at standard time. It has been suggested that a photograph of the face of a common watch might be taken at the instant an earthquake occurs. Were earthquakes so considerate as always to take place in the day time, there would be very little difficulty about the affair, but unfortunately they are not, and the difficulty is about a night illuminant because of course, the exposure must be very short to show the seconds hand of a watch fairly well and this necessitates a very bright artificial light. Some experiments made several years ago were very encouraging. Since then "magnesium cartridges" have been introduced, and there is no doubt that an arrangement could be devised whereby one of these could be ignited at the instant an earthquake occurred and, if the ignition took place fairly near the dial of a watch, a photograph showing the hands could be made even with a lens of only moderate angular aperture. It is somewhat doubful, however, whether such an instrument could be placed in the hands of one unskilled in the use of scientific instruments, and the object of watch photography is to get an appliance that may be placed in the hands of anyone.

On the other hand, it has suggested itself to the writer that the difficulty might be got over by fixing a minute silver bead on the end of each of the three hands of the watch. On the principle described above, in connection with the pendulum tremor recorder, the spot of light reflected by such beads ought to impress themselves on a plate with a fairly short exposure, even if the light be nothing more powerful than an ordinary lamp. The arrangement whereby a camera, with shutter to be released by an earthquake, a watch, and a lamp might be enclosed in a box so as to effect the desired result would not be complicated.

There are various other investigations in connection with which photography may possibly be used. Thus, although the motion of an earth particle during an earthquake has been very fairly investigated, there are still wanting data as to the relative motion of two earth particles at some distance from each other. It is of great importance to know what such relative motions are as, according to whether the motions of the earth particles at some distance apart are nearly in the same phase at the same time, or are in entirely different phases, is the effect of an earthquake on a building due to the inertia of the mass alone, or is due to racking. The construction of buildings to best resist these two destructive influences would be entirely different.

It is possible that photography may be used in connection with such investigations, but it is more probable that entirely mechanical means will be employed.

If the very long water level (at least several miles) proposed some time ago by Prof. Milne to discover whether there is any slow, tipping motion of the land in certain planes, be carried out it may be found convenient to register the height of the water at the two ends of the level photographically.

It would, however, be possible to go on indefinitely enumerating the purposes to which photography might be used in connection with seismology, but those given must suffice.