ON THE RECORDS OF THREE RECENT EARTHQUAKES.

BY

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At a recent meeting of the Seismological Society I exhibited an instrument, called an Astatic Horizontal Lever Seismograph, which was designed to record two horizontal components of earthquake motion, in conjunction with the time. I need not now describe the action of that instrument again, further than to remind the members of the society that in it there are two levers which press lightly on a continuously revolving plate of smoked glass, and move radially on it when a motion of the ground takes place, each lever recording that component of the motion which is at right angles to its length. One lever shows the N.-S. motion, the other the E.-W. motion, and the record in each case is magnified six times.

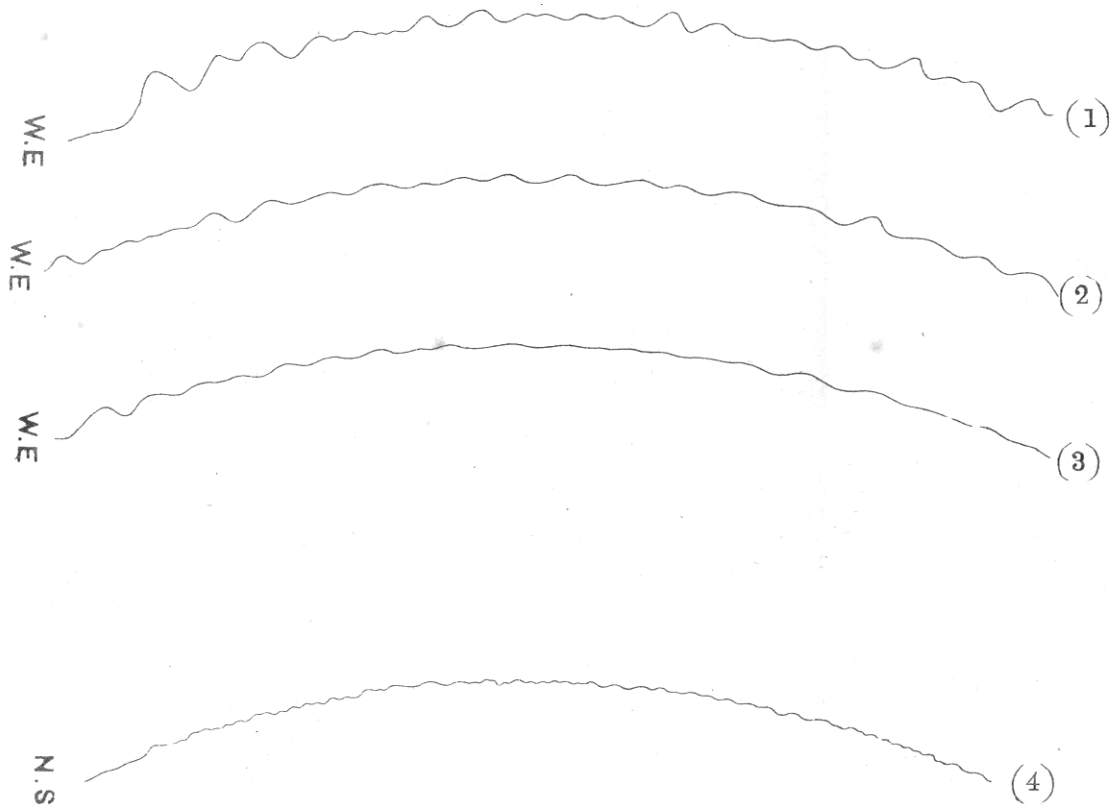
The instrument has been at work in the Engineering Laboratory of the University of Tokio since the beginning of last November. During that month it recorded a number of earthquakes, an account of which, communicated to the Asiatic Society of Japan, will be found in Vol. IX Part 1 of the Transactions of that society. Each of the earthquakes there described consisted of a large number of exceedingly minute and irregular oscillations. The greatest amplitude of total movement was only one-third of a millimetre. The motion generally began and always ended very gradually. The undulations in the records were so feeble as scarcely to admit of reproduction; and I was led by these early records to the somewhat hasty conclusion that a multiplying ratio of six to one was insufficient for a satisfactory representation of the minute movements we so frequently observe in Tokio.

More recently however we have passed through a period of seismic activity which has made me reject this opinion. During the last two months several earthquakes have occurred whose motion has been so considerable that any greater ratio than six to one would have given unnecessarily and even undesirably large records. Of two of these I am sorry to say I have no record: one happened whilst the glass plate was temporarily removed from the machine; the other was missed on account of an accidental stoppage in the clock. [This last was the unusually severe and prolonged shock of the evening of Dec. 23rd 1880]. Many other records, however, have been obtained, and of these I have selected the three largest to lay before the society. Two of the three earthquakes came during the morning of Jan. 24th 1881, at hours which I do not know exactly. The third came on Feb. 7th at 3.56 P.M.

The permanent records now exhibited to the society have been produced by taking photographs of the smoked plate after each earthquake. As soon as an earthquake is observed to have occurred the plate is removed from the machine (its place being supplied by another plate as quickly as possible) and the smoked surface is covered with transparent varnish in the manner practised by photographers. When the varnish is dry photographs of the complete plate are taken by a method often used by engineers for copying tracings and known as the "blue process". The paper is sensitised by a mixed solution of ammonio-citrate of iron and ferrocyanide of potassium and allowed to dry before exposure. Afterwards a simple washing in water serves both to develop and fix the picture, which is generally so sharply defined that measurements can be made from it quite as well as from the original curve on the plate. I should add that the clearness of the photographs now exhibited is due to the skill with which the process has been carried out by my assistant Mr. K. Sekiya, to whose intelligent and energetic cooperation I am much indebted in this, as well as in other matters.

To fit these for convenient publication the curves drawn round the plate have been cut into a series of successive arcs

Fig 1.



Jan 24 th 1881
First Earthquake.
Scale of Time $\frac{1}{2}$ inch to the Second.

which are shown in *fac-simile* in the accompanying figures 1, 2, and 3. These refer, respectively, to the three earthquakes named above. In the first and second case only a small part of the whole record is shown, but it includes the most interesting features of the movement. In the third case the greater part of the record is given, but even in it there is a large part omitted in which the motion was generally more minute than in the part which is given. I shall now consider the three records in detail.

I. (Fig. 1.)

The curves marked (1), (2), and (3) are successive portions of the record of East and West movement, from the beginning of the shock. A displacement upwards, in the figure, is toward the West, and downwards toward the East. This earthquake, unlike the greater number of those I have hitherto recorded, began with great suddenness. There is a large displacement towards the W., followed by a series of very irregular movements, producing the curiously jagged outline which is a marked characteristic of this curve. A close inspection will show that the first and principal movement towards the West was preceded by a very small one in the opposite direction. About the middle of (3) the motion appears to have almost wholly ceased, but it speedily reappears again and in fact there are several almost complete cessations followed by distinct though small movements before the disturbance came to an end. After (3) there are no features (except that just mentioned) of sufficient interest to make the remainder worth reproducing.

The mean speed at which the glass plate was moving under the pointers was 0.5 inch per second, but unfortunately both in this and in the other records described here, the rotation of the plate was far from steady, and hence I cannot speak with certainty as to the period of any one wave. Since these earthquakes occurred I have applied a simple but very effective governor to the clock (see "Nature" Vol. XXIII p. 473.) which will prevent this uncertainty from existing in subsequent records. The motion is distinctly traceable over a distance corresponding to one minute of time.

The greatest amplitude of motion is that of the initial shock, and is very nearly equal to 6 mm. This gives 1 mm. of actual motion. The principal (initial) shock is from E. to W.

The only indication given by the other lever is the exceedingly curious curve marked (4), the beginning of which is contemporaneous with the beginning of (1). It consists of small vibrations of much greater frequency than the main waves in the E. W. motion; but the sharp outline of the early part of the latter waves seems to show that they contain components of the same character as those in (4). I could not detect any shakiness in the apparatus which would account for these rapid vibrations. During the disturbance the E.-W. pointer travelled slowly in a direction which happened in this case to coincide with that of the principal movement (*i. e.* Westward). It is scarcely possible to set the levers so as to avoid altogether some tendency to creep in one or other direction during an earthquake, and in fact it is rather an advantage that there should be some such tendency, as it prevents the records from being superposed in successive revolutions of the plate. Of course while there is no earthquake the friction of the lever keeps it steadily tracing one and the same circular path.

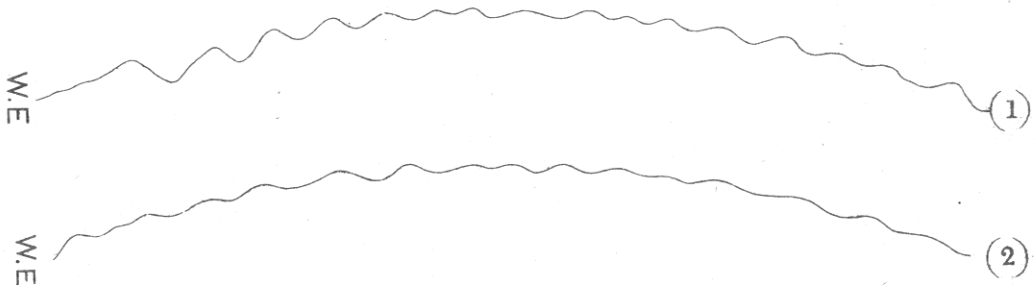
II. (Fig. 2)

This earthquake occurred early in the same morning as the last and both were found recorded on the plate when it was examined about 10 a. m. The records show quite clearly that this one was the second of the two, but beyond this I am not aware what their relation was in point of time.

Here also the motion was almost wholly in the E.-W. direction. The N.-S. pointer gave a very slight record, which has not been considered worth reproducing.

In this as in the former case the motion began suddenly, but the same peculiarity is to be observed, viz. that the principal initial displacement was preceded by a small one in the opposite direction. The principal movement was from W. to E, or opposite to that of the last shock and amounted to $\frac{3}{4}$ of millimeter. The motion continued for nearly one minute: only a small part, but the most important part, is given in the figure.

Fig 2



Jan 24 $\frac{th}{-}$ 1881
Second Earthquake.
Scale of Time $\frac{1}{2}\frac{in}{-}$ to the Second.

One more point remains to be noticed. Before this earthquake took place the recording lever had been well shaken into a position of stability by the preceding shock. Consequently its tendency to creep during this one was very small. It did however move *outwards* very slightly, that is, it continued to creep in the direction in which it had been creeping during the last earthquake. Now an examination of the beginning of this second shock shows that the large initial displacement (toward E.) was not followed by an equal or approximately equal displacement towards the other side of the mean position: in the return movement the pointer far from going beyond its original position barely reached it. This cannot be accounted for by a change towards E. in the position of the datum line (or line of no displacement) on the plate, for we know that the creeping tendency (such as there was) was towards W. and not towards E. It is clear therefore that the ground after being at first displaced in one direction did not then oscillate to anything like the same extent to the other side of its original position: in fact it barely reached that original position before it was again impelled once more in the direction of the first principal movement. Whether or no it finally after many oscillation recovered its original position we cannot say: there may or may not have been a permanent displacement continuing after the disturbance ceased. That is a matter to decide which is probably beyond the power of any observation. But at all events the record shows that the early oscillations of a point on the earth's surface had for their mean position a position which was not the original one occupied by the point, but was displaced from that original position towards the side to which the first great impulse acted.

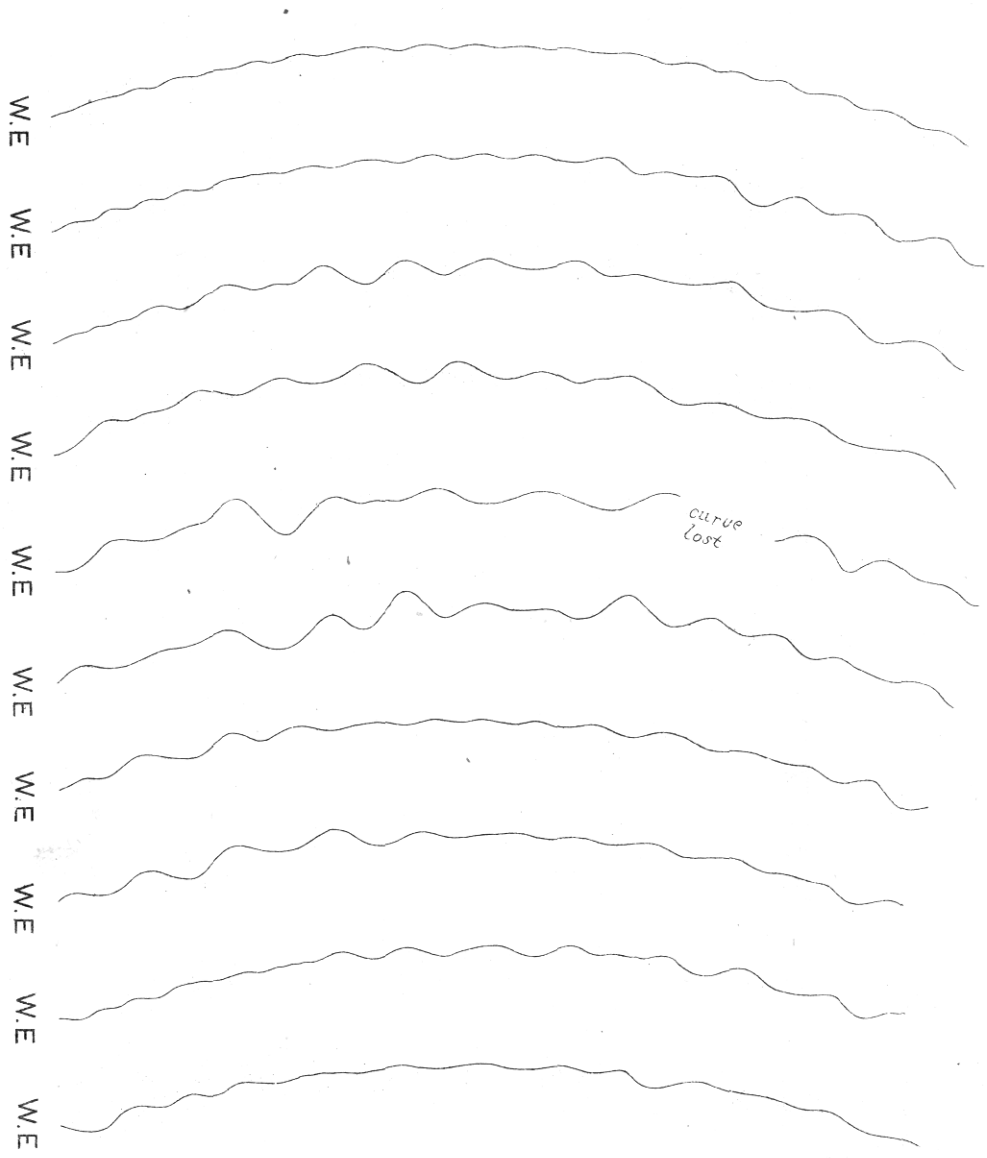
III. (Fig. 3.)

The third record which I have now to present to the society shows some striking points of difference when compared with the other two. As they were good examples of earthquakes which begin by a sudden and definite impulse, so this one exhibits the very common characteristic which I have already mentioned:—that of an exceedingly gradual beginning. The figure shows the chief part of the record, which

consisted of E.-W. motion. The only indication of disturbance shown by the other pointer was a very fine ripple of minute and rapid vibrations similar too but much smaller than those shown in Fig. 1, (4).

The motion was at first, and for some time, exceedingly minute, and it was not until about 30 complete oscillations had occurred that the amplitude became at all considerable. It then continued to increase irregularly, and, well on in the earthquake, attained a maximum of nearly 1 mm. (of actual motion). After this there were wide fluctuations, and several maximums and minimums in the amount of movement appeared before the close. The disturbance continued for nearly 3 minutes. Compared with other records the motion here was fairly regular. It was remarkable for its long period. The period of a complete wave was about 1 second, and to this circumstance we must ascribe the comparatively small impression of "intensity" produced by this earthquake upon persons who noticed it. In spite of the relatively great extent of the maximum motion, the shock, judged by one's feelings, was but slight. Others which have seemed more violent have had much smaller amplitude, but that has been more than counterbalanced by the frequency of their oscillations.

Fig 3



Feb $7^{\underline{th}}$ 1881 $3^{h}56^{m}$ PM
Scale of Time 0.4^{in} to the Second.