With the author's complimen[ts]


PHILOSOPHICAL TRANSACTIONS

OF THE

ROYAL SOCIETY OF LONDON.

SERIES A.

VOL. 194, pp. 135–174.


# III. ON THE PROPAGATION OF EARTHQUAKE MOTION TO GREAT DISTANCES.


BY

R. D. OLDHAM,

GEOLOGICAL SURVEY OF INDIA.



LONDON:

PUBLISHED FOR THE ROYAL SOCIETY

BY DULAU AND CO., 37, SOHO SQUARE, W.

CONTINENTAL AGENTS, MESSRS. FRIEDLÄNDER AND SON, BERLIN.

1900.

254. 29.3.1900.

*Price One Shilling and Sixpence.*

Of these the two records of the earlier of the two Turkestan earthquakes of 15th August, 1897, being 13 minutes in advance of the time of origin, may very probably be attributed to some local shock. Three of the others are practically simultaneous with the origin, and one, omitting the Tokio record of the Argentine earthquake, about 7½ minutes later than the origin. That is to say, the record begins from 5 to 15 minutes before the arrival of the condensational waves.

It is very difficult to decide whether these early commencements of the record have any real connection with the earthquakes they appear to refer to, or are due to other, possibly local, disturbances which happened to coincide approximately with the greater earthquake.

On the one hand the number of cases in which there is an early commencement of the record seems too great for the connection to be fortuitous. Excluding the second Turkestan shock, where the record began at Ischia and Catania about 13 minutes before the earthquake, and the disturbance may well be attributed to some other cause, we have no less than five out of ten distinct shocks, in which there is a commencement of the record in advance of the disturbance of what I have called first phase.

On the other hand there is the want of accordance in the times, and the fact that the early commencement was in each case only found at a single station; as these are about evenly divided between the light and heavy pendula, there is no guide as to the nature of the disturbance.

If due to the principal shock and not to local disturbances, these early commencements of the record can hardly be attributed to any form of wave motion set up by, and at the same time as, the earthquake. They would, in this case, have to be attributed to premonitory disturbances of a nature very different to that of the main shock, for, though unfelt in the neighbourhood of the origin, the initial energy of the disturbance would have to be great enough to affect instruments at distances ranging from one ninth to one quarter of the circumference of the earth.

On the whole, then, it seems more natural to attribute these early commencements, which show no concordance in their times as compared with each other, to local disturbances, or at any rate to some cause other than the earthquake with which they are approximately coincident. A possible exception to this is the Tokio record of the Argentine earthquake; this, as suggested above, may be due to the earlier emergence of condensational waves which have traversed the central core of the earth, as compared with those which have not penetrated so deep and, though traversing a shorter course, have done so at a lower rate of propagation.

The results obtained in the preceding investigations may be summarized as follows:—

1. The complete record of a distant earthquake shows three principal phases of increase of displacement followed by decrease, the phases being marked by a more

or less well defined change in the character as well as the amount of the displacement. Of these the third phase is the most readily and constantly recorded, the second less so, and the first is the phase most frequently absent.

2. The disturbance of the first and second phases being recorded by heavy pendula, possessing great inertia, with greater constancy and concordance than by light horizontal pendula specially designed to detect surface tilting, we may conclude that the motion is principally of a to-and-fro nature, and that the records are due to the inertia of the pendula, rather than to a tilting of the surface. This conclusion has been come to by previous writers in the case of particular shocks.

3. The times of arrival of the first two phases, when plotted, form a curve of increase of apparent velocity with distance, consistent with the hypothesis that they represent the times of arrival of elastic waves propagated through the earth at rates which increase with the depth below the surface.

4. The increase of rate of propagation with depth appears to be a constant function of the depth, at any rate as far as the greatest depth reached by the waves which emerge at a distance of 90° of arc from the origin. Beyond this depth, which may be put at about 0·45 of the radius, there are some indications of a rapid increase in the rate of propagation.

5. The time curves drawn through the times of commencement of the first and second phases, if continued to the origin, give initial rates of propagation in tolerably close agreement with the probable initial rates of propagation of condensational and distortional waves in continuous rock.

6. We may consequently accept the conclusions, that the first phase represents the arrival of condensational waves, and the second phase of the distortional waves, each of which have travelled along brachistochronic paths through the earth.

7. The disturbance of the third phase differs from that of the first, or second, phase in that the light pendula with photographic registration are even more sensitive to it than the heavy pendula whose freedom of movement is trammelled by the friction of their mechanical record. From this we may conclude, that the record is due not to inertia, but to a tilting of the instrument as a whole; a conclusion which is borne out by the nature of the record in those instruments which trace the displacements on a surface moving with sufficient rapidity to give an open record. This is the phase of the long surface undulations, resembling the swell of the ocean, whose character has been recognised and acknowledged since 1894.

8. The apparent rate of propagation of the waves of this phase shows no sign of varying with the distance from the origin, but is constant at all distances, or at most subject to a very slight and slow change. From this it may be concluded that they are propagated as surface undulations and that, in their case, the true and apparent velocities are everywhere identical.

9. The rate of propagation is not, however, constant in the case of all earthquakes, but the waves set up by the greatest earthquakes travel at a higher speed than those set up by lesser ones; from this it may be concluded that the rate of propagation is, in some way not yet worked out, a function of the size of the wave.

10. The rate of propagation of the waves of this phase is, in the case of great earthquakes, higher than that which has been calculated for purely elastic surface waves, and from this, and from the fact that their rate of propagation seems to be a function of their size, it is probable that their propagation is, at least in part, gravitational.