

to the axis of folding of the older Pliocene rocks in Hawke's Bay, and to the general axis of New Zealand. They are also just on the outside of the sloping plateau which about 250 miles to the E.S.E. rises above the sea as the Chatham Islands. Between this line of origins and the south-east coast of the North Island is a trough in the ocean-bed with a depth of 1,000 to 2,000 fathoms (AA).

It is probable that the earthquake of the 9th August was due to sudden slipping along a fault-plane, or other similar movement that occurred in the process of the "repacking" of the deeper rocks, consequent upon the continuance of the folding which the geological evidence shows to have been going on for many ages.

The maximum displacement or amplitude of an earthquake particle may be calculated from the other elements of the earthquake: the data in this case give 2–2.5 mm. as the maximum horizontal displacement; the vertical displacement would consequently be not greater than  $\frac{1}{2}$  mm. or  $\frac{1}{50}$  in.

The isoseismals, or lines of equal earthquake-intensity, marked on the map confirm in a general way the conclusions already established in regard to the region of disturbance.

[I am indebted for valuable observations and notes of the earthquake to the Secretary of the Post and Telegraph Department and his officers, especially to Mr. Keys of Napier, and to many private persons, the careful notes collected by Mr. R. P. Soundy, of Dannevirke North School, being of great interest.]

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ART. XLVI.—*The Path of Earthquake-waves through the Earth.\**

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[Read before the Wellington Philosophical Society, November, 1904.]

Plate XXXIII.

As it has been stated that the apparently high speed of the preliminary tremors in large earthquakes is to be accounted

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\* Since writing this paper I have received from the Earthquake Investigation Committee of Japan a copy of a paper on the same subject by Mr. Imamura, of the Hongo Observatory, Tokyo, in which the writer arrives at the same conclusion from calculations based on nineteen severe earthquakes recorded at all the chief seismological stations of the world. My paper was written ten months before the receipt of Mr. Imamura's

for by the probable fact that they pass from the origin along chords to the several places of observation, I have examined the records of several earthquakes as given by Milne seismographs at different stations situated all over the world, with the object of determining the question whether the waves in question are propagated along arcs or chords of the earth.

Taking the great Guatemala earthquake of the 19th April, 1902, as a fair specimen of the calculations, the evidence is, in my opinion, almost wholly in favour of the theory that the fine vibrations commonly called "preliminary tremors" do not travel along chords, as some have maintained, but along arcs at no great depth, the most probable speed being, in the case of this earthquake, 15.6 kilometers per second.

The table shows the distances (arcual and chordal) of the observing stations from the origin of disturbance, and the times of arrival of the preliminary tremors.

The diagram shows the same facts in a graphical form, the dots showing the points on the velocity-curve for the same places on the assumption of paths along arcs, the small crosses corresponding points on the assumption that the paths were chordal. The scale of the diagram is so chosen that the same unit represents 1,000 kilometers along the axis of  $y$ , or 100 seconds along the axis of  $t$ . Hence the velocity at a distance  $y$  from the origin =  $10 \frac{dy}{dt}$  kilometers, which can be read directly from the diagram.

It does not seem possible to make any assumption of varying rigidity and elasticity of the internal rocks that would account for the varying velocity on the latter assumption; whereas the fact that on the former hypothesis Imamura's curve is almost a straight line shows that the velocity is nearly constant ( $\frac{dy}{dt} = \text{constant} = 1.56$ ; therefore  $v = 15.6$  kilometers per second, as stated above).

Theoretically, the velocity should be constant while the waves are travelling through a homogeneous medium. Hence we may fairly conclude that the waves travel parallel to the surface at a uniform depth such that the elasticity and rigidity of the rocks allow of a high velocity, probably between fifteen and twenty miles below the surface.

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paper, and I think it due to myself, as well as a confirmation of his investigation, to publish in brief the results at which I had arrived. But his diagram represents the facts so much better than the diagram accompanying my paper that I have substituted for the latter a modification of his diagram, introducing a simplification which I venture to think gives a still clearer graphical representation of the facts. This modified diagram I have called "Imamura's curve."