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671ST ORDINARY GENERAL MEETING,

HELD IN COMMITTEE ROOM B, THE CENTRAL HALL, WESTMINSTER, S.W., ON MONDAY, JANUARY 19TH, 1925, AT 4.30 P.M.

E. WALTER MAUNDER, ESQ., F.R.A.S., IN THE CHAIR.

The Minutes of the previous Meeting were read, confirmed and signed, and the Honorary Secretary announced the election of the Rev. Henry W. Bromley, D.D., as a Member, and of Mrs. Ida Case as an Associate.

In introducing the Lecturer, the CHAIRMAN said:—

Ladies and Gentlemen,—There have been many great and terrible earthquakes throughout the entire length of human history, and unhappily there have often been observers of them. But it is only within the last few years—practically within the present century—that earthquakes have been studied scientifically. There are still but very few mathematicians and physicists who have given systematic attention to earthquake phenomena, but prominent among these is Dr. Dorothy Wrinch, of University College, London, and Fellow of Girton College, Cambridge, whom I have much pleasure in introducing to you. I will now ask Dr. Wrinch to read her paper on "Seismic Phenomena."

SEISMIC PHENOMENA.

By DR. DOROTHY M. WRINCH.

THE modern science of Seismology has developed very rapidly since its beginnings about the year 1880. The sharp earthquake of February 22nd, 1880, which did a considerable amount of damage in Yokohama and Tokyo, had one important scientific consequence. It led to the formation of the Seismological Society of Japan, which had, for its object, the study of earthquake phenomena. The indefatigable labours of Milne, Knott, Ewing and other European scientists resident in Japan, and the cordial support of a number of prominent Japanese, were indeed responsible during the next few years for the foundation of the science of Seismology. It became in this short span a branch of natural philosophy, and the foundations were well and truly laid. The fertility of the applications of the science and the rapid progress in knowledge which the last few years has seen bears eloquent testimony to this fact.

The development of Seismology as a branch of science is due, in the first place, to an important experimental discovery made by Milne. It was found that by means of a delicate pendulum an earthquake could be registered at places at a great distance away from the scene of its occurrence. This discovery at once opened the way to the collection of seismic data, for, evidently, records of an earthquake from observers at different places could be used comparatively and might reasonably be expected to give important information with respect to the incidence of earthquakes in various parts of the earth.

It has long been realized that certain regions of the earth's surface are specially subject to earthquakes, and it is owing to this grim privilege that Japan in the East and Italy in the West led the way originally in the production of seismological observations. Milne catalogued 8,331 earthquakes which happened in Japan between the years 1885 and 1892. The frequency of earthquakes in Japan, however, varies very much from one district to another, and these 8,331 quakes apparently belong to fifteen distinct districts, outside which there are practically no earthquakes at all. Even, in fact, in Tokyo the number of earthquakes varies very much with locality. Yearly catalogues of earthquakes were prepared by Mallet, Perry and others, and in recent years M. de Montessus de Ballore, in his work *Les Tremblements de Terre*, has given a detailed account of all the earthquake regions of our globe.

When he returned to this country in 1895, Milne set up his observatory at Shide in the Isle of Wight, and by the installation of his instruments at a number of stations all over the earth he inaugurated the first seismological service. The comparative data thus obtained were of the greatest importance, and led rapidly to an increased knowledge of the properties of the earth. This work has been carried on under the auspices of the British Association, and the Committee is still doing yeoman service to Seismology in collecting data in all the five continents. Owing to the splendid lead given by Milne, and the inspiration, skill and devotion of Professor Turner, the seismological service has had the tremendous advantage of a central clearing station, of recent years at the Oxford University Observatory, where year by year the observations of all the stations are collated and examined, and published in annual reports to the Seismological Committee of the British Association.

The present flourishing state of Seismology is entirely due to the splendid way in which observations of seismic phenomena have been contributed by large numbers of people in different parts of the world. As early as 1877, for example, detailed descriptions of seismic phenomena at sea were made by captains of ships. Thus Captain Murdoch, of the *Denbighshire*, when in the neighbourhood of St. Paul Island, recorded two severe shocks. I quote from his log, which is one of a number collected and discussed by Rudolph.

"The first shock was like a jarring of everything in the ship. On deck it appeared as if the chain cables were running out and the topmost yards were coming down by the run, and it seemed as if every step we took on deck we must fall down. This shock lasted 30 or 40 seconds. All hands had rushed on deck, thinking the ship was on shore, and while sounding the pump the second shock occurred. It was sharp and instantaneous, as if a large cannon had been fired immediately below the ship. . . It was a volcanic eruption or explosion. The noise that accompanied the first shock was like the low groaning of distant thunder, but yet it appeared near and about us."

The land surface of the globe is only a small part of the whole surface of the earth, and there must evidently be a very large number of earthquakes originating below the sea for which no observations by observers on land are available. It is, therefore, of special importance to have records of seismic phenomena at sea. The ships at sea, however, are comparatively few in number, and indeed are few and far between compared with the great stretches of ocean over which they navigate, and the records of earthquakes occurring under the ocean beds are necessarily more incomplete than the records of other earthquakes.

In spite of all these difficulties there is a certain amount of information available as to the frequency with which earthquakes have occurred during the last forty years in different districts of the earth's surface. The seismic maps of the world are of interest in this connection.* A well-known earthquake region is in Italy and the Alps, which has, according to de Ballore, as large a number of earthquakes for its size as Japan. The strongly marked regions appear to be situated on the borders of continents and in areas where geological changes are known to be in progress. Thus, for example, there are areas of strongly marked seismic activity all round the Pacific Ocean, from the East Indies, the Philippines, Japan and Alaska, and along the west coast of America. Thus statistics collected of recent years

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* See Knott, *The Physics of Earthquake Phenomena*, p. 97.

show that for every earthquake felt in Great Britain there were (roughly speaking) 50 in Japan and 158 in Greece, the areas of these countries being taken into account.

We have already mentioned the discovery made by Milne in Japan which formed the starting-point of Seismology as an exact science dependent on accurate observations and capable of development in accordance with the general principles of science. In Milne's seismograph we have, as its fundamental characteristic, a horizontal pendulum fitted at its inner end with an agate cup which presses against a steel pivot-point screwed into a vertical iron pillar cast in one piece. The pendulum is supported at its outer end by means of a fine steel wire which passes to a pin at the top of the pillar. Now, when an earthquake is in progress, it is found that there is, in general, a definite movement of the pendulum. In fact, even when the earthquake is at a great distance away (and it is by no means unusual for a seismograph of this type to record seismic movements occurring at a distance of 10,000 kilometres), there is apparently a definite movement of the earth which can be detected by a pendulum, provided that the adjustment of the pendulum is sufficiently delicate. There are many very important mechanical devices for measuring accurately and conveniently the motion of the pendulum, and, in fact, in the Milne seismograph the pendulum carries at its outer end a small transverse plate of aluminium with a narrow slit parallel to the pendulum, which, by means of an ingenious arrangement of a slit in the case which covers the instrument, and an illumination from above, enables a small dot which corresponds to the intersection of the slits to be cast on the surface of some bromide paper, which is wound on the surface of a cylinder made to revolve uniformly, the speed of revolution of the paper being nearly 4 mm. per minute. In this way an accurate and convenient record is obtained of the motion of the tip of the pendulum. It is interesting to see the type of record made on a Milne seismograph when a great earthquake is in progress. There are, first of all, certain oscillations which are called the primary phase, and after a time, which varies for earthquakes at different distances away, the seismogram changes its type, and there is then usually a large movement denoted by S, which initiates the second phase. Its incidence is less sharply marked than P, and it is sometimes very indistinct. This second phase also lasts for a time, depending on the distance away of the earthquake, and then the whole appearance of the seismogram changes and assumes a strongly periodic character. This phase, which is called the long-wave phase, is usually marked by a few waves of period about 20 seconds, gradually increasing in amplitude. After reaching a maximum amplitude, the waves subside and pass through a succession of maxima before merging into the "tail" or "coda" of the earthquake.

Now the appearances of seismograms to the trained eye present a curious uniformity in spite of the minor variations which occur. And it is found that these characteristic phases of the primary waves and the secondary waves and the long waves are capable of a very important, and at the same time simple, explanation, if we assume that the earth is an elastic solid. For it is known that an elastic solid is capable of transmitting various kinds of waves. It can have a longitudinal wave which moves with a certain velocity V_1, and it can have a transversal type of wave which moves with a different velocity V_2, and when the elastic solid has a shock at a certain point waves of both these kinds are sent out from the centre of the disturbance. In the first kind of waves the various particles move backwards and forwards in the line of wave propagation. In the second kind of waves the particles oscillate backwards and forwards at right-angles to the direction in which the wave is moving. Now, if the earth is an elastic solid, we may expect two trains of waves travelling with two different velocities to be sent out if there is a shock at any point. The starting-points of the two phases P and S can now be interpreted as the arrival of the two types of waves—first the longitudinal waves, which move faster, and then the slower transverse waves. And with this hypothesis we find that the velocities of the two waves are about $5\frac{1}{2}$ km. per second and 3 km. per second in the case of fairly near earthquakes. It is a great achievement to have obtained this amount of agreement between the actual seismograms of various earthquakes at many different stations and the predictions of the theory of elasticity which asserts the existence of two waves of these types. This chapter of seismology, indeed, shows the tremendous difference between a set of observations which have been welded into a science and observations which are discrete and disconnected and which have no underlying theory behind them. Science really begins when some generalization is made which is capable of covering data already obtained and which predicts other data. Now in Seismology, the moment it became reasonably probable that these well-marked P and S phases represented the arrival of the two kinds of wave, it at once became possible to predict within limits the time each type of wave would take to go a certain distance. And evidently, also, the quicker wave gains a definite amount for every kilometre traversed. Thus a certain definite interval separating the two types of wave in any record betokens a definite distance away of the disturbing cause. Thus, a record at Edinburgh, say, might show a time difference of a certain number of seconds in the start of the P and S phase ; from this we could deduce the distance away of the disturbance. If, then, records at other observatories are also available, we may be in a position to assert that the earthquake was at x km. from one station, at y from another, and at z from a third, and, therefore, that it must lie in the neighbourhood of Tokyo. In this way the many earthquakes already treated have been located. It is to be noticed that the larger the number of records available the larger is the degree of accuracy to be expected in the location of the earthquake itself. And it is also plain that a fair distribution of seismographs all over the world is to be desired, not merely the excessive equipping of stations which lie for the most part in one or two continents only. It is for this reason that Milne was so anxious to establish seismographs in countries not hitherto making any records of seismic phenomena, and, owing to his great zeal, fifty of his seismographs have been distributed all over the world, so that no continent, and few large countries, have remained unrepresented in the international seismological service of the world. Seismology is essentially a science which needs the co-operation of many countries and peoples, and it provides a strong link between the people of the East and those in the West whose scientific pursuits have led them into these absorbingly interesting fields of study.

In spite of the large number of observations of earthquakes which are now available, there is a real need for more material. It is by no means an easy task to deduce the velocities of the P wave and the S wave from the mass of observations, for in the case of each earthquake we do not in general know the exact location of the earthquake. And even if we know the point of the earth's surface under which the earthquake occurs, we do not know how far down the actual disturbance took place. The place at which the disturbance takes place is generally called the "focus," and the point of the earth's surface directly above it is generally called the "epicentre." Thus, in the case of any earthquake, we have to find not only the epicentre—which, in the case of a large earthquake, may be only too obvious if much damage has been caused, but which is not known to any degree of accuracy in the case of small earthquakes—but also the focus. Now, it is clear that if reliable information were available as to the rates at which the P and S wave travel it would give us some help in our task of making an estimate of the depth of the earthquake focus, for the deeper the focus the longer the path traversed by the waves in getting from the disturbance to an observing station at a certain specific distance from the epicentre of the earthquake. It is, therefore, of great importance to obtain information as reliable as the circumstances permit of the velocity of the P and S waves. It was with a view to obtaining information of this kind that Dr. Jeffreys and I undertook an enquiry into the waves caused by a great explosion at the works of the Badische Anilin und Sodafabrik, at Oppau, in the Bavarian Palatinate, on September 21st, 1921. Oppau is about 5 km. north-west of Mannheim and stands in the Rhine valley. The shock of this tremendous explosion was so great that waves of the P and S type were started in the earth's crust, and these waves, which spread out in all directions, were recorded at Strasbourg, which was 110 km. away, at Nördlingen, 175 km. away, at Zürich, 240 km. away, and at München, which is 282 km. away, by the seismographs which were at work in the various observatories. Now, as we already knew that the disturbance took place at a certain definite place, and took place, in fact, on the surface of the earth, there was no ambiguity at all about the focus or epicentre of the disturbance, and it was, therefore, a simple matter to deduce the velocities with which the primary and secondary waves travelled through the earth's crust. We found the velocities to be 5·4 km. per second for the primary waves and 3·15 km. per second for the secondary waves. With this information, it is now possible to obtain more reliable information as to the precise location of earthquakes which are not more than 200 or 300 km. from the recording station. If it were possible to make a similar investigation in the case of even greater explosions which are sufficiently strong to enable a record to be obtained at much greater distance, further information would become available which would materially increase the probability of making a more correct estimate of the distance away of seismic disturbances, even when these disturbances are —as in fact they generally are in practice—at a far greater distance away than 300 km. But there appear to be grave difficulties in the way of staging explosions of the required magnitude.

It would be valuable and interesting if some reliable estimates could be made of the depth of earthquake foci in the various great earthquakes. Opinions are very much divided on this topic, Prince Galitzin putting down an estimate of even 1,250 km. for an earthquake he recorded. And it is of interest not only to Seismology but to Geology to know the depth at which these seismic disturbances originate. Seismologists are, in fact, making important and valuable contributions to geological knowledge by their discoveries. The province of the geologist is an extremely difficult one, in so far as it deals with conditions in the interior of the earth. The depth which he can study by direct observation is insignificant in comparison with the radius of the earth. It is, therefore, of extreme importance and interest if, by means of any other science, information can be obtained as to the conditions prevailing in the interior of the earth. Now, it has already been explained that fairly reliable information has been obtained as to the velocity of waves in the surface layer, at least in South Germany, the Netherlands and Alsace, from the Oppau explosion. In so far as the velocities of waves in an elastic solid are known if the elasticity and density of the solid are known, these results yield some information as to the geological properties of the surface layer of the earth, at least in these districts. In the same way, if we are able to discover the velocities of waves coming through parts of the earth below the surface layer—and it is these waves which we are recording in the case of disturbances at a greater distance away than about 400 km. —we shall obtain information for the geologist as to the conditions in the earth below the surface layer. And this information it would be very difficult to get in any other way.

There is outstanding one of the most important of the practical problems connected with Seismology, namely, the question of the possibility of predicting earthquakes. This is a problem of the greatest difficulty and complexity. Much attention has been devoted by the pioneers in Seismology to the possibility that the occurrence of earthquakes may show a relationship to tidal influences. They have also considered how far barometric influences can be correlated with the occurrence of earthquakes. The influence of the sun and moon has also been taken into account. But unfortunately, so far, the results obtained tend to show that earthquakes cannot be correlated with tidal, barometric, solar, lunar or thermometric influences. Their occurrence is apparently a more complicated matter, and we must, therefore, reluctantly allow that, so far, Seismology is not within sight of a solution of this problem. It is not to be wondered at that this problem should prove to be of so obstinate a character, in view of the amazing difficulty of Seismology, in so far as it depends on the conditions prevailing throughout a large part of the earth's interior. But, on the other hand, it cannot well be doubted that progress is being made on the right lines. It is time and again the case in the development of a science that a real understanding of the phenomena involved must precede the solution of any practical problem associated with them, however pressing this problem may be. This characteristic of science is forcibly brought to our notice in Seismology, for the need for knowledge which will enable us to predict earthquakes is indeed urgent. The activities of the peoples of the countries of marked seismic activity might be considerably extended if warning of coming disasters were available. The death-roll in the last Japanese earthquake covered a terrific amount of suffering and anguish, and any possibility of mitigating the lot of those who live in these geologically unstable regions must be pressed to the uttermost. But, alas! it seems to be probable that such possibilities will be realized only after considerably more knowledge has been acquired of conditions in the earth's interior. The real understanding of Nature, even in one small section of it, is a prodigiously difficult task. It can only be attained by the enthusiastic co-operation of keen far-sighted investigators. The real understanding of even a small corner of Nature is an aim which has spurred on the unnumbered investigators who have been toiling throughout the centuries. Natural Philosophy, which is the ordered expression of the facts of Nature, is not a simple structure; it is woven and interwoven with strands from many different domains. No observation or fact of Nature can ultimately be allowed to remain outside the structure of science. If facts remain outside, the principles of science must be altered as far as is necessary for their inclusion within the scheme of science. The study of the structure of science is an absorbing one, in spite of tremendous difficulties.

The contemplation of the orderly development of facts of Nature brings some understanding of the external world, which is, alas! necessarily incomplete. In science we seek to link together facts of different kinds so as to see their interrelations: we endeavour so to relate different facts that some may be viewed as logical consequences of the others in the light of general scientific principles. When these relations have been found, it is only the more fundamental facts from which the others may be deduced which need further investigation. This process is going on day by day in the many different sciences, and as time goes on the number of facts to be fitted into the scheme of science increases and the development of the general principles also proceeds. The aim of scientists is to discover the general principles of science, and to make as small as possible the fundamental facts which by means of these principles are sufficient to account for all the other facts of Nature. At any stage, it is only these general principles and the sifted residue of facts which stand in need of explanation. The huge mass of other facts follow logically, though in many cases by no means simply, from the so-called fundamental ones. But at this point the scientist has to stop; he cannot go behind the fundamental facts and principles. From time to time scientists may alter these facts and principles, and suggest new principles which give a more adequate account of the structure of science. This is the case in the recent developments of the theory of Relativity, in which new principles have been formulated by Einstein and other workers in science by means of which certain domains of science can be reconstructed. But the situation from the epistemological point of view remains the same. he ultimate residue of principles and facts which science has to assume remains, and as scientists we can never go further than to reconsider and reconstruct in the light of science's latest discoveries. But the mystery behind still remains.

Discussion.

The Chairman said: I have listened to Dr. Wrinch with very great interest, and, I trust, with much profit, for indeed, hitherto, Seismology is a subject which I have not studied at all. I have only had one personal experience of an earthquake—a very small earthquake indeed—but, if I may use the expression, one of the same class as the Oppau explosion, to which the lecturer referred in the paper to which we have just listened. Like the Oppau earthquake, it resulted from an explosion, and the focus and epicentre were coincident. I am referring to the shock caused by the great explosion which took place at Silvertown about the middle of the war. My wife and myself were sitting in my study on that evening in a window looking over the Thames, and towards Silvertown, in Essex, about a couple of miles distant from us. Suddenly we felt our solidly built little cottage—some of its walls are 3 feet or more in thickness—rise, roll and drop, just as an anchored boat will do when a wave passes under it. We had just time to say to each other "We never felt anything like this before," when the noise of explosion, which had come through the air, reached us and was followed by the crash of breaking windows.

Practically all that I know about seismic phenomena comes from two papers which I heard in December, 1922, at the Royal Astronomical Society. The first was given by Dr. Wrinch and her collaborator, Dr. Jeffreys, and was on the Oppau explosion; the other was by Dr. Jeffreys on the Pamir earthquake of February 18th, 1911. In this last the earthquake was synchronous with the fall of a mass of rock, 3 cubic kms. in bulk, and the question was discussed as to which was the cause and which the effect. Dr. Jeffreys concluded that it was the fall of rock that caused the earthquake, so that in this case again the focus and epicentre were coincident; but the earthquake was a world-shaking one. From his study of the system of waves arising from this earthquake, Dr. Jeffreys deduced the important conclusion that the foci of the earthquakes used in the standard tables by seismologists in no single case exceeded the depth of 200 kms.

Remarks by Mr. F. J. Lias: Members have fortunately so little personal knowledge of earthquakes that they may be interested to hear something about them from an associate who has lived in Japan for 20 years, and who has "experienced" dozens, and whose acquaintance with Prof. Milne—"Earthquake Johnny," as he was affectionately called by his friends—dates back to 1888.

The old mythological tradition in Japan was that earthquakes were caused by a dragon of immense proportions living in the Pacific Ocean, whose tail was in the Gulf of Tokyo; and that when the dragon wriggled, the earth shook. Nowadays, however, more commonplace and practical solutions are sought, and perhaps the most favoured belief is that seismic disturbances are the result of volcanic action on the earth's surface, and more particularly are due to the caving-in of large masses, or of subterranean or sub-oceanic explosions caused by the infiltration of water into the still glowing interior of the earth, which in volcanic areas is not far distant from the surface.

The earth's crust also is far more plastic than most people are aware, and on one occasion I myself actually *saw* an earthquake coming towards me along the street in slow, shallow, rhythmic waves, resembling the slight swell of the sea some days after a storm has passed away. There is also little cause for astonishment at slight earthquake shocks being felt in one part of a city when in another nothing is recorded, as this may be due to the underlying formation—rock being a good conductor, whilst sand, gravel, or any loose geological formation acts as a shock absorber.

At sea earthquakes are rarely felt unless excessively severe, but ships at anchor are particularly subject to shock, owing to the vibrations being communicated to the hull by means of the anchor chains, whilst the greater plasticity of the water, as compared with what we erroneously call *terra firma,* causes shocks thus communicated to be more distinctly felt.

In regard to the longitudinal and transversal waves as recorded by the seismograph, the possibility of the original wave encountering some exceptionally solid form of resistance, in the shape of deep-rooted rock formation, might be borne in mind. The confused seas caused by the *ricochet* of waves from a breakwater will provide a *simile,* and there is also the possibility of an initial seismic disturbance (say a subterranean explosion) reaching a given spot more or less simultaneously (1) by the shortest route direct from the focus, and (2) by the longer way of the plastic surface of the globe.

The following information from a friend recently arrived from Nagasaki may be of interest :—

"Professor Omori, Milne's immediate successor at Tokyo, was of opinion that earthquakes might be due to pressure, contraction and expansion, and that barometric pressure might well exercise a distinct influence. For instance, a long period of high barometric pressure, followed by a sudden drop, would bring about an unequal balance of pressure on the earth's crust, which might react under this influence, particularly where the crust is thin. The choking of natural vent-holes (volcanoes, geysers, etc.) would cause an increase in internal pressure; and this instability would be likely to develop along a fault in the geological structure, with the possible accompaniment first of sudden expansion (explosion) and then contraction (caving in) of the earth's surface. The influence of the tides on the seismograph is plainly visible near the sea, where a downward and upward movement of the crust is regularly recorded as the waters ebb and flow."

In conclusion, there is nothing that I know more truly awful, in its proper meaning, than a severe earthquake. One feels that the bases of all one's belief in stability are undermined, and that there is nothing left on which to build one's hopes. No experience will steel one against this impression of fear, even when one's nerves are proof against ordinary sensations of alarm. In Japan the old proverb runs that there are four things on this earth of which to be afraid: *Jisshin, Kaminari, Kwaji, Oyaji*—Earthquake, Thunder, Conflagration, Father-in-law; and of these earthquake is easily first. So that anything which will tend to the further explanation of so terrifying an item in their lives, will indeed be a godsend to the sixty millions of people inhabiting Japan.

Mr. HOSTE remarked, with reference to a previous speaker's prophecy of seismological discoveries, that however gratifying it might be to sufferers from earthquakes to have them scientifically explained, he did not quite see what comfort could accrue to persons in the threatened areas to be told an earthquake was shortly due unless some cure could be found. At present the only cure seemed to be to "clear out." He wanted to ask the learned lecturer whether any light had been thrown on the vexed question of the condition existing in the centre of the earth, by variation in the speed of the seismic waves? Would it be possible to compare the rate of the waves when passing through a short piece of normal earth crust in a comparatively non-earthquake region and similar waves in a highly excitable region such as Messina or Tokyo, where the molten condition might be supposed to be existing more generally and nearer the surface?

Mr. WILLIAM C. EDWARDS said: I am sure that we have all enjoyed this instructive and interesting lecture. I am reminded by it of the pleasant lectures of Milne, who was often not a little humorous.

I hope that some day our learned lecturer will come again and address us upon the earthquakes of Holy Scripture and the Holy Land.

There are not many recorded in God's Word, for although the Holy Land in its making, or preparation for God's chosen people, has probably at some distant date been the scene of the most severe and tremendous earthquakes, it has not, in historical times at least, suffered so much or so often as many other parts of the world.

When the great earthquake occurred in Calcutta the famous missionary, Carey, sat down and read the third verse of Psalm xlvi, which seems to refer to or to contemplate an earthquake: "Though the earth be removed and though the mountains be carried into the midst of the sea; the waters thereof roar and be troubled; the mountains shake with the swelling thereof." I don't think that there can be any reasonable doubt that an earthquake is here envisaged.

In the days of King Uzziah there was also a great earthquake, which seems to have so impressed the minds of people that for a long time they appear to have spoken of events as having happened "before" or "after" *the* earthquake; thus the Prophet Amos writes, "The words that he saw in the days of Jeroboam two years before the earthquake" (Amos i, 1).

The memory or tradition of that awful event was still fresh in the minds of people nearly a century later and when Zechariah wrote (xiv, 5), "Ye shall flee, like as ye fled from before the earthquake in the days of Uzziah King of Judah, and the Lord my God shall come and all the saints with thee."

In Zech. xiv, 4, we have also a prophecy of a coming earthquake, perhaps two following earthquakes:—"The Mount of Olives shall cleave in the midst thereof toward the East and toward the West, a very great valley, and half of the mountain shall remove toward the North and half of it toward the South."

When our Lord was leaving the Temple for the last time before His Crucifixion, the Disciples on this same Mount of Olives asked Him three questions:—When shall these things be? What the sign of Thy coming? and the Consummation of the Age? (Matt. xxiv, 3). In effect, the same questions are repeated in Mark xiii, 4, and Luke xxi, 7. Now observe carefully the answers.

There are the wars of Nation against Nation and Kingdom against Kingdom, famines and pestilences, and " earthquakes in divers places " (Matt. xxiv, 7) ; " there shall be earthquakes in divers places " (Mark iii, 8) ; " and great earthquakes shall be in divers places " (Luke xxi, 2).

These are the united signs that are apparently to precede the coming of our Lord, and I should like to ask our learned lecturer if we have not in late years been having an exceptional number of earthquakes following the world war of Nation against Nation and Kingdom against Kingdom, as well as famines and pestilences; if so, may not these be the signs that our Lord gave His disciples then, and gives to us now, to warn us to watch, wait, and be ready for His speedy return ?

Dr. WRINCH's reply : The science of Seismology and the practice of systematic seismological observation have only a short history at present. And although there have been observations and records of earthquakes, as, for example, those to which Mr. Edwards has referred in biblical times, we have unfortunately no means whatsoever of making a comparison of the frequency of earthquakes in these times and the frequency during the last few years. If there has indeed been an increase in seismic activity during the years since the war, in comparison with the activity in biblical times, it would be of importance to physicists and geologists to know it ; but I can think of no data which would put us in a position to support the assertion on grounds of scientific observation. On the other hand, if we turn to the question of the prior probability of the increase of seismic phenomena—and it is, of course, frequently necessary in scientific theory to turn to prior probabilities when data are lacking—I still feel quite unable to support the suggestion.

The CHAIRMAN said : Just a week ago I received from Canada a paper containing a report—partly scientific, partly descriptive—of the great Japanese earthquake of September 1st, 1923. Captain Robinson, Commander of the Canadian Pacific ss. *Empress of Australia,* which was about to leave Yokohama en route for Vancouver, uses almost the very words which Mr. Lias has given us in his description just now. " The land was rolling in waves, like a succession of fast moving ocean swells." More than half a million houses were destroyed, and more than 100,000 lives were lost.

There is an urgent need for knowledge which will enable us to predict earthquakes so that some warning may be given of coming disaster.

On behalf of the Victoria Institute, and as representing this meeting, Dr. Wrinch, I desire to thank you for your most clear and instructive paper.

In reply to a question by Mr. MAUNDER as to whether the P and S waves moved uniformly at all distances from the epicentres, Dr. WRINCH sent the following table, which is a shortened form of that generally used in calculating the distance of the epicentre from the observing station :—

Deg.	P. Sec.	S. Sec.	S.P. Sec.	Deg.	P. Sec.	S. Sec	S.P. Sec.	Deg.	P. Sec.	S. Sec.	S.P. Sec.
1	15	28	13	51	553	991	438	101	855	1,565	710
10	150	269	119	60	612	1,103	491	110	897	1,647	751
20	281	503	222	70	677	1,226	549	120	942	1,729	787
30	388	694	306	80	739	1,343	604	130	988	1,801	813
40	475	847	372	90	796	1,454	658	140	1,031	1,864	833
50	547	979	432	100	851	1,556	705	150	1,071	1,917	846