Seismological Investigations.—Eighth Report of the Committee, consisting of Professor J. W. JUDD (*Chairman*), Mr. J. MILNE (*Secretary*), Lord KELVIN, Professor T. G. BONNEY, Mr. C. V. BOYS, Professor G. H. DARWIN, Mr. HORACE DARWIN, Major L. DARWIN, Professor J. A. EWING, Dr. R. T. GLAZEBROOK, Professor C. G. KNOTT, Professor R. MELDOLA, Mr. R. D. OLDHAM, Professor J. PERRY, Mr. W. E. PLUMMER, Professor J. H. POYNTING, Mr. CLEMENT REID, Mr. NELSON RICHARDSON, *and* Professor H. H. TURNER. (*Drawn up by the Secretary.*)

[PLATE I.]

CONTENTS.

I. *General Notes on Stations and Registers.*

DURING the past year the registers issued are Circulars Nos. 6 and 7. These refer to Shide, Kew, Bidston, Edinburgh, Paisley, Toronto, Victoria (B.C.), San Fernando, Cairo, Cape of Good Hope, Calcutta, Bombay, Kodaikanal, Batavia, Baltimore, Mauritius, Trinidad, Irkutsk, Perth, Wellington, Christchurch, Cordova (Argentina), Honolulu, and Tokio.

Mr. F. A. Chaves, Director of the Meteorological Service in the Azores, writes that the two seismographs referred to in the Report for 1902 are now in working order, one at Ponta Delgada, 25° 41′ 15″ (1h. 42m. 45s.) W. long., and the other at Horta, 28° 38′ 26″ (1h. 54m. 34s.) W. long.

From Professor A. F. Griffiths, President of the Oahu College, and Professor W. D. Alexander, also in Hawaii, I learn that the seismograph sent to Honolulu in 1899 is at the U.S. Magnetic Observatory near Pearl Harbour. Mr. Weinrich, who has charge of the instrument, has installed it on a concrete pier rising from the bed rock. The instrument room measures 8 feet by 12 feet. It has stone walls 16 inches thick, and is lined and ceiled with boards. The room has ventilators, but the temperature is almost uniform at 75° F.

Observers using or interested in the establishment of the British Association type of instruments who have during the past year visited Shide were Mr. W. J. Kenny, H.B.M. Consul, formerly of Hawaii; Professor H. F. Reid, of Baltimore; Mr. C. Michie-Smith, of Kodaikanal; and Mr. E. Human, of Colombo. The latter gentleman, whose object was to discuss observatory sites and the working of seismographs, came at the suggestion of the Colonial Office.

As might be anticipated, now that experience has been gained in working the instruments, correspondence with stations has considerably decreased.

II. *The Origin of large Earthquakes recorded in* 1902 *and since* 1899.

On the accompanying map (Plate I.) the origins for 1902 are indicated by small numerals which correspond to earthquake numbers in the Shide registers. These are divided into districts marked alphabetically. The large numerals give the number of large earthquakes which have originated in each district since 1899. Maps corresponding to the one here given can be found in the 'British Association Reports' for 1900, p. 70, and 1902, p. 64. The methods employed in determining origins are referred to in the Report for 1900, pp. 79 and 80.

The chief feature in the map for 1902 as compared with those for preceding years is the increase of activity shown for the Caucasian-Himalayan district K and the decrease in the Alaskan and Andean regions (A and D). If we omit districts E and A then, as pointed out by Professor Libbey, a circle of about 70° radius and centre 180° E. or W. long. and 60° N. latitude in Behring Straits passes through the seismic regions of the world which are at the present time most active. On the map this is indicated by a dotted line. The Pacific origins fall on a circle about 75° in radius, with its centre 180° E. or W. long. and 30° S. lat.

Mr. J. H. Jeans, in his paper on 'The Vibrations and Stability of a Gravitating Planet,'[1] suggests that these regions lie on a great circle of which England is the pole, this circle being the equator of the supposed pear-shaped form of the world. The equator for the pear-shaped form, according to Professor W. J. Sollas,[2] has its centre about 6° N. lat. and 30° E. long.

III. *Earthquakes and Changes in Latitude.*

In the 'British Association Report' for the year 1900, p. 107, the wanderings of the pole from its mean position are compared for the years

[1] *Phil. Trans. Royal Soc.*, vol. cci. p. 183.
[2] 'The Figure of the Earth,' *Quart. Journ. Geol. Soc.*, vol. lix. Part 2.

Origins for 1902 are indicated by their B.A. Shide Register number. Earthquake districts are indicated A, B, C, &c., and the number of earthquakes which since 1899 have originated from these is expressed in large numerals. Observing stations are named.

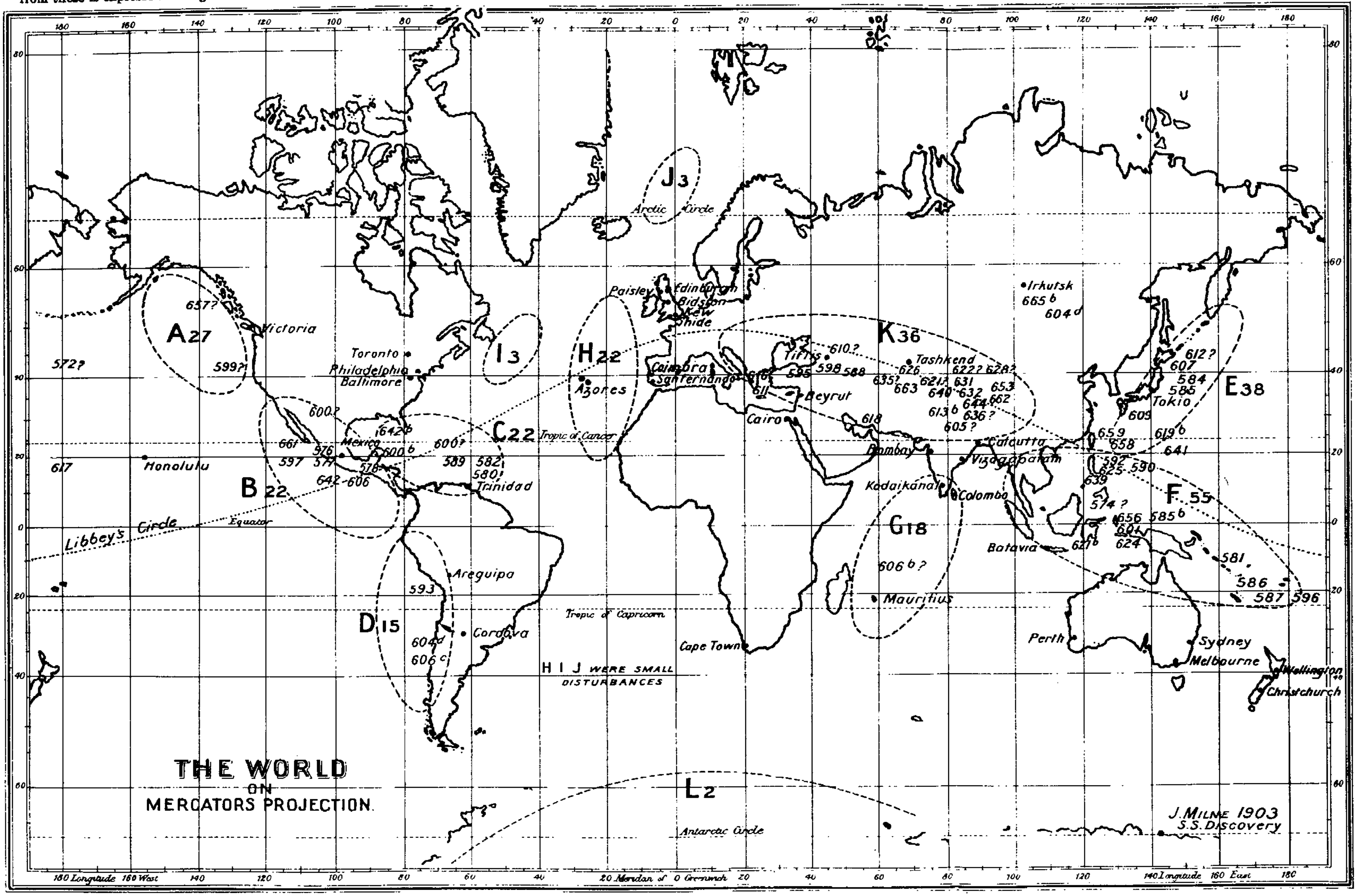


FIG. 1. *Illustrating the Report on Seismological Investigation.*

1895 to 1898 inclusive, with the registers of earthquakes which during that period have disturbed the whole world, or, at least, continental areas. A suggested conclusion was that when the pole displacements were comparatively great large earthquakes were frequent, and *vice versa.* The inference to be drawn from the following note is that this same type of earthquake has been frequent when the change in direction of the movement of the pole has been marked. In the following table the years (1892 to 1899) have each been divided into ten parts, and the large earthquakes which occurred during each of these intervals are given by numerals.

The earthquake registers from which the latter figures have been abstracted are as follows :—

1. March 14, 1892 to Aug. 7, 1893.—Strassburg and Nicolaiew (see 'Horizontalpendel-Beobachtungen,' &c., von Dr. E. von Rebeur-Paschwitz. 'Beiträge zur Geophysik,' Band II.).
2. Aug. 7, 1893, to Sept. 12, 1894.—Charkow (see 'Ergebnisse der auf der Charkower Universitätssteinwarte,' mit den v. Rebeur'schen Horizontalpendel angestellten Beobachtungen, v. Prof. G. Lewitzky).
3. Jan. 1, 1894, to Dec. 31, 1896.—Italian and other stations (see '*Bollettino della* Società Sismologica Italiana,' 1895.
4. Jan. 1, 1897, to Dec. 31, 1902.—Registers from stations widely spread over the world, published by the Seismological Investigation Committee of the British Association.

Although these registers are comparable so far as world-shaking earthquakes are concerned, it is evident that in the last list very large earthquakes are included which could not have reached stations in Europe. For this reason, so far as actual frequency is concerned, Registers I., II., and III. are not comparable with No. IV.

Periods	1892	1893	1894	1895	1896	1897	1898	1899
0–1, Jan. 1 to Feb. 5 .	no obs.	8	12	1	2	3	4	9
1–2, Feb. 5 to Mar. 14 .	"	22	11	1	1	7	4	9
2–3, Mar. 14 to April 19	14	16	13	1	1	3	8	10
3–4, April 19 to May 26	8	32	19	0	4	5 or 7	5	4
4–5, May 26 to July 1 .	0	41	3	1	3	7 or 11	8	6
5–6, July 1 to Aug. 7 .	8	24	14	1	0	5	7	16
6–7, Aug. 7 to Sept. 12	8	20	10	2	3	9	5	6
7–8, Sept. 12 to Oct. 19	12	12	no obs.	0	5	10	6	10
8–9, Oct. 19 to Nov. 24	7	6	"	2	5	7	1	7
9–10, Nov. 24 to Dec. 31	10	9	"	1	0	5	5	5

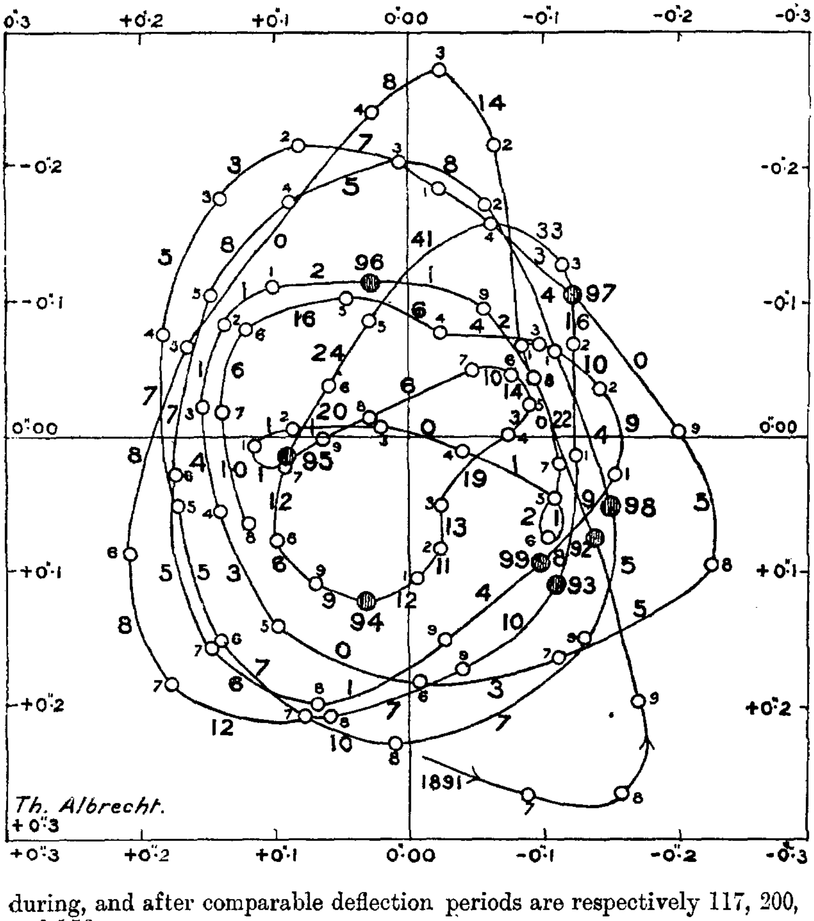
Earthquake figures connected by brackets refer to two periods, each of 36·5 days, when the change in direction of pole movement was marked. In the following table the total number of earthquakes which occurred in each of these two periods is so far as possible compared with the total number of earthquakes which were recorded in equal intervals of time (73 days) before and after the deflection periods.

Earthquakes before deflection :	no obs.	8	38	18	—	22	no obs.	1	3	3
Earthquakes during deflection :	*22*	*20*	*73*	*21*	24	*24*	*2*	*3*	*2*	*10*
Earthquakes after deflection :	8	17	44	—	22	no obs.	1	2	7	3

Earthquakes before deflection :	3	14	8	15	14	10
Earthquakes during deflection :	10	17	13	11	*19*	*22*
Earthquakes after deflection :	12 or 18	9	15	6	10	17

Out of sixteen deflections there are twelve instances where the greater number of earthquakes have taken place during the deflection period. In three instances the number for the deflection period, although exceeded by number before or after that period, has been greater than the average of the sum of the preceding and succeeding numbers. In only one instance (February 5 to April 19, 1896) have the earthquakes in the deflection period had a distinct minimum. The totals for before,

FIG. 2.



during, and after comparable deflection periods are respectively 117, 200, and 153.

One inference from this investigation is not that the molar displacements accompanying large earthquakes result in polar displacements, but rather that changes in direction of these latter movements, particularly when the rate of change has been rapid, have had an influence upon earthquake frequency. From Albrecht's figure of movements of the North Pole (fig. 2), on which the numbers of large earthquakes corresponding to different periods are given, the periods of rapid change can be seen.

IV. *On the Comparison of Records from three Milne Horizontal Pendulums at Shide.*

At Shide three Milne horizontal pendulums are installed on two similar brick piers, 2 ft. 6 in. distant from each other. Each pier is 1 ft. 6 in. square, and rises 4 feet above its footings, which rest on concrete. One pier was built in May 1897, and the other in November 1902. The instruments are described in the 'British Association Report' for 1902, p. 60. The older of the two piers carries the type instrument, which has a period of 16 seconds and records east and west movements. This is referred to as pendulum A. Pendulum B has the same period, and is oriented in the same direction as pendulum A. Pendulum C, which with B forms the Yarrow instrument, has a period of 20 seconds and records north-south motion.

The following results refer to seismograms obtained between November 21, 1902, and March 24, 1903, or in the Shide register Nos. 659 to 693.

Times of Commencement.—Out of twenty-six cases the times of commencement of A and B have in eleven instances never differed more than one minute. When this limit has been exceeded the movements to be measured have usually been slight thickenings or blurs. Comparing C with A or B, out of nineteen cases there are ten instances falling within the one-minute limit.

Times of Maxima.—The times at which maxima have occurred as recorded by A and B have not differed more than two minutes in ten instances out of fourteen records. When this limit has been exceeded the records usually refer to slight thickenings in traces in which one out of several points might be selected as a maximum.

The maxima for C agree within the two-minute limit with those of A and B eight times.

Amplitudes.—The amplitudes recorded by A and B have in twenty-five cases only once differed 1 mm. from each other. The records obtained for C have not differed greatly (·5 to 1·5 mm.) from those shown by A and B. Out of twenty instances the C records were eleven times larger, three times smaller, and nine times equal to those shown by A and B.

Durations.—Out of twenty-one instances the records of C were three times greater, six times smaller, and twelve times practically equal to those obtained from A and B.

These comparisons are similar to comparisons of records from two similar seismographs made by Dr. Charles Chree, F.R.S., at Kew.[1]

V. *On the Comparison of Earthquake Registers from Shide, Kew, Bidston, and Edinburgh.*

In the 'British Association Reports,' 1901, pp. 44–50, and 1902, pp. 73, 74, references are made to series of earthquake records obtained at Kew, Shide, Bidston, and Edinburgh, stations which are respectively situated on alluvium, chalk, sandstone, and volcanic rock.

The following notes chiefly refer to observations made between July 1 and December 31, 1902, during which period the instruments at the different stations have been so adjusted that 1 mm. deflection of the outer end of the boom corresponded to a tilt of the bed plate of 0″·5.

[1] See *B.A. Report*, 1901, p. 51.

Earthquake Frequency.—The number of earthquakes recorded were as follows:—

July to December, 1902	Bidston,	69	Shide,	40	Edinburgh,	37	Kew,	30
During the year 1902	„	134	„	78	„	70	„	64
During 11 months in 1901	„	94	„	90	„	85	„	63
Total for two years		228		168		155		127

Each of the earthquakes considered was recorded at more than one station, and therefore it is extremely unlikely that artificially produced disturbances have been included in the computations.

Earthquake Duration.—Between July and December there were ten earthquakes, each of which was recorded at all four stations. The total number of minutes which the instruments were caused to move by these disturbances were:—Edinburgh, 691; Kew, 610; Shide, 606; and Bidston, 545.

Amplitudes.—The sum of the maximum amplitudes in millimetres for ten earthquakes was as follows:—Shide, 19·4; Kew, 14·1; Edinburgh, 12·0; Bidston, 9·0.

These quantities regarded as angular displacements may be respectively read as 9″·7, 7″·2, 6″·5, and 4″·5. Add to these the corresponding quantities for earthquakes recorded between January and June, then the totals for the year 1902 are: Edinburgh, 21″·5; Shide, 21″·1; Kew, 20″·9; and Bidston, 13″·2.

If in making these comparisons the large earthquakes are omitted, then the amplitudes of motion as recorded at different stations are practically identical.

Commencements.—Out of thirteen records (June to December 1902) at Bidston the commencements have been the earliest—or not more than two minutes later than those recorded at other stations—nine times, at Shide seven times, at Edinburgh six times, and at Kew three times.

Conclusion.—For the present, at least, the conclusions arrived at are as follows:—

1. Bidston records the greater number of earthquakes and obtains earlier commencements for the preliminary tremors more frequently than at other stations.

The durations and amplitudes recorded at Bidston are less than at other stations.

2. Kew records the least number of disturbances, and commencements are frequently late. Durations and amplitudes are similar to those obtaining at Shide.

3. At Edinburgh and Shide, frequency, time of commencement, and amplitude are similar, but at the former station the duration is greater than at the latter.

VI. *Earthquake Commencements as recorded at Strassburg and in Britain.*

The records referred to in the following note are those obtained in 1902 from the Rebeur-Ehlert pendulums at Strassburg or Hamburg[1] and the Milne pendulums installed at Kew, Shide, Bidston, and Edinburgh. The multiplication of the Strassburg apparatus is about eight

[1] See *B.A. Report*, 1898, p. 268.

times that of the instruments employed at the stations in Britain, from which it might be inferred that very minute preliminary tremors might be recorded, and therefore earlier commencements of motion be calculated for these Continental stations than would obtain in Britain.

With the assumption that the greatest difference in time that could exist between the commencement of motion at these two groups of stations is four minutes, the comparison of fifty-six records common to Germany and Britain leads to the following :—

In twenty-four instances the difference in the times of commencements does not exceed the four-minute limit. These in the Shide register correspond to numbers 581, 584, 585, 586, 588, 590, 595, 606, 614, 616, 619, 619*b*, 625, 627, 636, 641, 642*c*, 644, 653, 658, 661, 662, 663, 665.

The remaining thirty-two instances where this limit has been exceeded refer to twenty-one mere thickenings of the trace and eleven to earthquakes with moderate amplitudes. These thirty-two instances may be divided into two groups, there being twenty-three cases where the British records are late relatively to those noted in Germany, and nine when the German records fall behind those obtained in Britain. The British records, which are late, are numbers 578, 580, 583, 597, 598, 600, 600*b*, 606*b*, 611, 613*b*, 617, 618, 622*b*, 624, 633, 639, 640, which are all minute thickenings on the trace, and 589, 592, 599, 609, 612, and 659, which are well-defined records.

The German records, which are late, are numbers 576, 582, 610, which, as noted in Britain, are small, and numbers 572, 593, 601*c*, 607, 626, 642, which are large or fairly large disturbances. The number of disturbances as recorded in Germany with too late commencements, oddly enough, is exactly the same as recorded in Britain.

The conclusions to which these comparisons point are :—

1. For recording small tremors which do not extend over great areas the Rebeur-Ehlert pendulum, as installed at Strassburg, possesses advantages over the Milne horizontal pendulum as installed at stations co-operating with the British Association.

2. For recording the commencements and, it may be added, other phases of earthquake motion which affect the world as a whole the accuracy of the records from both types of instruments is practically identical.

In connection with these conclusions it must be pointed out the fineness of the trace obtainable with the British Association type of instrument partly compensates for its comparative want of sensibility. The particular sensibility given to it is one that is obtainable at a variety of stations. Were this increased, which is easily done by raising its period from sixteen to twenty, or even forty, seconds, when it would be more responsive to tremors, then at many stations it would be found that diurnal and other wanderings, together with air tremors, would seriously interfere with the recording of earthquakes. Instruments of the Rebeur-Ehlert type, with large multiplication, not only consume what for many would be a prohibitive quantity of photographic paper, but, as for example at Trieste and Kremsmünster, they are frequently recording movements which are not required.

VII. *The Velocity of Propagation of Earthquake Vibrations.*

In the 'British Association Report' for 1902, p. 65, a diagram is given showing the time taken for various phases of earthquake motion to traverse arcs or distances corresponding to arcs of various lengths.

From this diagram an arcual velocity for the maximum of large wave movement may be derived of 3 km. per second. For the commencement of such movements this would be slightly increased, and would then accord with observations made by Dr. F. Ōmori, who obtains for this particular phase an arcual velocity of 3·3 km. per second.

To give actual velocities or average velocities for the preliminary tremors, not knowing the paths they follow, is accompanied by uncertainties. What can be done, and is shown in the following table, is from the above-mentioned time curve to calculate velocities on the assumption that the paths have been arcs or have approximated to chords, or we can make similar calculations from a time curve so corrected that 11 and 17 minutes are respectively taken to traverse distances corresponding to 70° and 150°. The justification of reducing the steepness of the preliminary tremor curve and yet keeping within the results of observation rests upon the analysis given on pp. 5 and 6.

Average Velocities of Preliminary Tremors.

—	10°	20°	30°	40°	50°	60°	80°	90°	150°	—
Uncorrected time curve on arcs.	3 to 5	9·2	9·2	9·2	9·2	9·6	9·8	10·1	12·9	Km. per second.
Uncorrected time curve on chords.	3 to 5	9·2	9·1	9·1	9·0	9·2	9·1	9·1	9·4	,, ,, [1]
Corrected time curve on arcs.	3 to 5	10·5	11·1	10·6	10·9	11·1	12·3	12·8	16·3	,, ,,
Corrected time curve on chords.	3 to 5	10·5	10·9	10·3	10 5	10·6	11·3	11·5	12·0	,, ,, [2]

From the above table it will be seen that if the preliminary tremors follow paths which are arcual, then there is a marked increase in speed of transmission on long paths as compared with the speed upon short paths. If, however, the paths approximate to chords, then velocities which are approximately constant prevail. The deviation from being actually constant along chordal paths is apparently a slight increase in speed along paths taken nearer and nearer to the centre of the earth.

The high values of 10·5 to 12 km. per second suggest a high rigidity for the world, whilst the approximate uniformity of speed within its core indicate approximate uniformity in those properties which determine the rate at which it transmits vibrations. Unless it is assumed that as we descend in the earth electricity and density increase in the same ratio, to which hypothesis there are objections, the inference is that the nucleus of the world has a density more nearly uniform than is generally assumed.

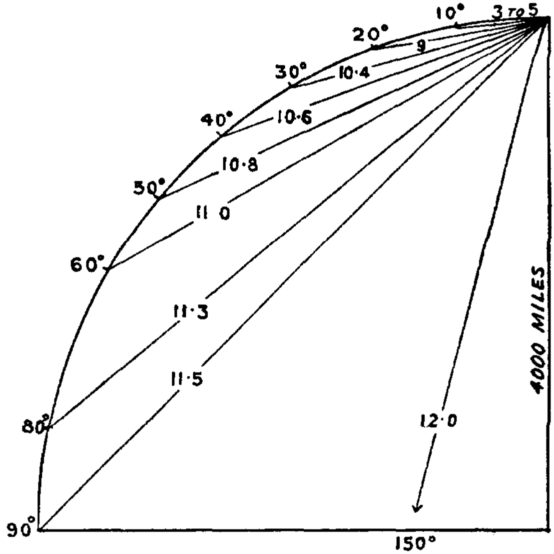
To satisfy the interpretation given to these seismometrical observations what is required is a globe with an approximately uniform nucleus not less than $\frac{19}{20}$ of the earth's radius covered by a shell which passes rapidly upwards into the materials which constitute the crust of the world.

[1] In an article in *Nature*, April 9, 1903, p. 538, on 'Seismometry and Geite,' *minimum* values are given for these quantities.

[2] If these last values are plotted on squared paper a curve for their mean position gives the following values: 3 to 5, 9·0, 10·4, 10·6, 10·8, 11·0, 11·3, 11·5 and 12·0 km. per second.

That low velocities are found on wave paths corresponding to chords of less than 10° suggests that this crust is not more than forty miles in thickness. This seismometrical determination of thickness for the earth's crust accords, it will be observed, with determinations of the same quantity which are chiefly dependent upon the effects of high temperatures assumed to prevail at such a depth. At fusion temperatures liquefaction

[FIG. 3.—Average Velocities for Preliminary Tremors if propagated along Chords.]



is a state for many substances which is promoted by pressure, whilst at still higher temperatures Arrhenius points out that whatever the pressure might be it seems probable that fluids would become gaseous, and such gases would be dense, but slightly compressible and viscous. What the velocity table (as it now stands) indicates is that a crust passes rapidly into a nucleus which is exceedingly rigid and fairly homogeneous. A specific gravity can be defined for this nucleus which will meet the requirements of gravitational observations, and it seems likely that the same may accord with the tests of the astronomer.

Isomorphous Sulphonic Derivatives of Benzene.—Fourth Report of the Committee, consisting of Professor H. A. MIERS (*Chairman*), Dr. H. E. ARMSTRONG (*Secretary*), Professor W. P. WYNNE *and* Professor W. J. POPE. (*Drawn up by the Secretary.*)

THE object the Committee have primarily in view is the crystallographic study of the complete series of sulphochlorides and sulphobromides derived from the isomeric dichloro-, dibromo- and chlorobromo-benzenes.

The results obtained in the case of the para- and two of the three series of meta-derivatives have been referred to in previous reports. It may be pointed out that whereas no evidence was obtained that the 1 : 4 derivatives exist in polymorphic forms—the five compounds measured