Seismological Investigations.—Eleventh Report of the Committee, consisting of Professor J. W. JUDD (*Chairman*), Mr. J. MILNE (*Secretary*), Lord KELVIN, Dr. T. G. BONNEY, Mr. C. VERNON BOYS, Sir GEORGE DARWIN, Mr. HORACE DARWIN, Major L. DARWIN, Professor J. A. EWING, Dr. R. T. GLAZEBROOK, Mr. M. H. GRAY, 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.*

THE registers issued during the past year are Circulars Nos. 12 and 13. They refer to Shide, Kew, Bidston, Edinburgh, Paisley, Toronto, Victoria (B.C.), San Fernando (Spain), Ponta Delgada (Azores), Cape of Good Hope, Alipore, Bombay, Kodaikânal, Batavia, Perth, Trinidad, Christchurch, Cairo, Irkutsk, Baltimore, Beirût, Honolulu, Cheltenham (Md. U.S.A.), and Vieques (Porto Rico).

From the United States Coast and Geodetic Survey the Secretary has received records from the Milne pendulum established in Honolulu, together with records from Bosch-Omori pendulums installed at Vieques (Porto Rico), Cheltenham Md. U.S.A., and Sitka.

These registers appear in Circular No. 13.

Records have not yet been received from Melbourne, Sydney, and Arequipa; while registers from Tokyo, Wellington, Philadelphia and Mexico should be brought up to date. The Seismological Committee of the British Association would be greatly indebted to the Directors of Observatories at these places if they would kindly forward copies of their observations.

During the last year Milne pendulums have been installed at Old Frensham Hall, Haslemere, Surrey, at the University in Malta, and at the National Observatory in Paris.

All instruments record photographically on cylinders moving at the rate of 25 c.m. per hour. The two first instruments are single component, while the latter gives a two-component record. The instrument at Haslemere was established by the late Hon. Charles Ellis, who, in addition to giving this assistance to observational seismology in this country, forwarded to the Secretary a cheque for 200*l.*, to be used as he considered best to assist seismological research. Your Committee suggest that it be employed towards the general expenses at Shide station, particularly in connection with an increase in office accommodation. Mr. Richard Cooke, The Croft, Detling, Maidstone, has kindly sent 1*l*. 1*s*. as an annual subscription for the support of seismological research.

II. *The Situation of Stations.*

Continued from 'British Association Report,' 1905, p. 84.

Achalaki.

The town lies on a plateau. Beneath the town we find two lava streams, the lower one trachytic with a columnar structure, here dense and there porous. Above this there is a dolomite schist, in parts solid and in others porous. These are separated from one another by schistose sandstone of Miocene age with slate and layers of coal.

Batoum.

The town lies in the Kachaber low ground, which is formed of the deposit of the river Tschoroch. A vertical section through the low ground shows the following horizontal strata in downward succession:—

Humus	0·355 metre
Hard clay	2·84 "
Clayey sand mixed with pebbles . . .	1·42 "
Sand	1·065 "

The heights surrounding the town consist of different sorts of andesite and tufa.

Borshom.

The little town of Borshom lies in the valley of the river Kura, and its tributary rivers Borshomka and Tschornaja Retchka.

The tectonic formation which is shown in the neighbourhood of Borshom may be summarised as follows: Steep sloping strata of the Eocene period intermingled with andesite strata form anticlinal and synclinal folds. The protruding ends of strata consist of andesite lava in layers and streams.

The sedimentary formation is represented by marl and argillaceous sandstone. The marl possesses the peculiarity of being broken into small pieces; the sandstone is traversed by a system of perpendicular clefts inclining to a cubical cleavage.

The region on the right side of the Kura forms a plateau which is an anticlinal; the middle of the plateau coincides with the ridge of the anticlinal, and strikes N.W.–S.E.

Upon the left side of the Kura, where the seismic station is situated, there is a deposit of sandstone and marl in layers with a uniform dip of 15° N.E.

Schemacha.

The town lies partly on the slope of the valley of the river Dsoga-Lawa and partly in the river valley itself. No account of the structure of the district has been published. Many varieties of sedimentary rocks belonging to the Tertiary period are to be found.

In the town towards the south, Muschelkalk schist supported by clay slate dips N.W.

On the southern face of the height which rises above the town one finds the same limestones exposed, which in their higher part dip S.E., but in the lower part W.S.W.

In a deep ditch not far from the prison we find laminated plastic clays which support intermediate layers of marl, sandy clay, and lime sandstone.

To the south of the town, not far from the village Bojat, one finds the following strata exposed in this order downwards:—

(*a*) Yellow and brown coloured sandy clay.
(*b*) Various layers of insignificant thickness of yellow and white clays.
(*c*) Shell limestone (Muschelkalk) with Cardium (*sic*) and Mactra.
(*d*) White and yellow porous sandstone with shells.

Derbent.

The town lies on the lower shore of the Caspian Sea.

The nearest point of interest from the town is the mountain Dschalgan, whose steep brows approach the town from the south-west. To the southerly side of the mountain we find a synclinal fault which stretches N.W.–S.E., and dips south-east. In the direction of the town the tectonic structure becomes tolerably complicated, and the connection of the Dschalgan synclinal with the flat dome-shaped anticlinal which comes to sight on the north side of the town is not yet explained. Tertiary deposits as well as the Quaternary Loess formation are also found. The latter deposit stretches from the sea-shore at Derbent to a height of 100 fathoms up the brow of the Dschalgan.

In the sea-cliffs, not far from the railway station, shell lime rocks come to view.

The remainder of the Dschalgan heights are formed of limestone, sandstone and clay. Along the south-east brows of the Dschalgan, not far from the fortress, one finds the following strata cropping up in ascending order:—

1. Grey and coffee-brown coloured sandy clay.
2. 3–2 inches of clay strata with ferruginous grains.
3. Layers of white sandy clays.
4. Grey shell limestone (holding Mactra), 17–15 fathoms thick.
5. Dividing layers of marl clay with broken pieces of Mactra shells, 3 inches.
6. Grey Mactra shell limestone, 14–15 fathoms.
7. Dividing layer clay marl, 14 inches.
8. Yellowish solid limestone with few large shells of Mactra, such as Vitaliana, d'Orb.

Tiflis.

The town lies on the slopes of the valley of the river Kura.

With the exception of a few places, where primitive rock comes to view, the surface formation of the Tiflis valley is composed of clayey sandstone and loam deposits, whose thickness amounts in places to 80 feet and more. This is covered with horizontal strata of alluvium.

The heights in the environs of the town consist of the above rocks, together with sedimentary and volcanic rock débris, which are cemented together by a clayey medium.

In an exposure on the right bank of the Kura, in the immediate neighbourhood of the seismic station, one finds more or less thinly laminated clay sandstone of a grey colour; the same stratification is to be seen in the bottom of a deep trench which surrounds the station. The foundations of the station, as well as all seismographs, are directly set on the original rock.

III. *The Origins of Large Earthquakes in* 1905.

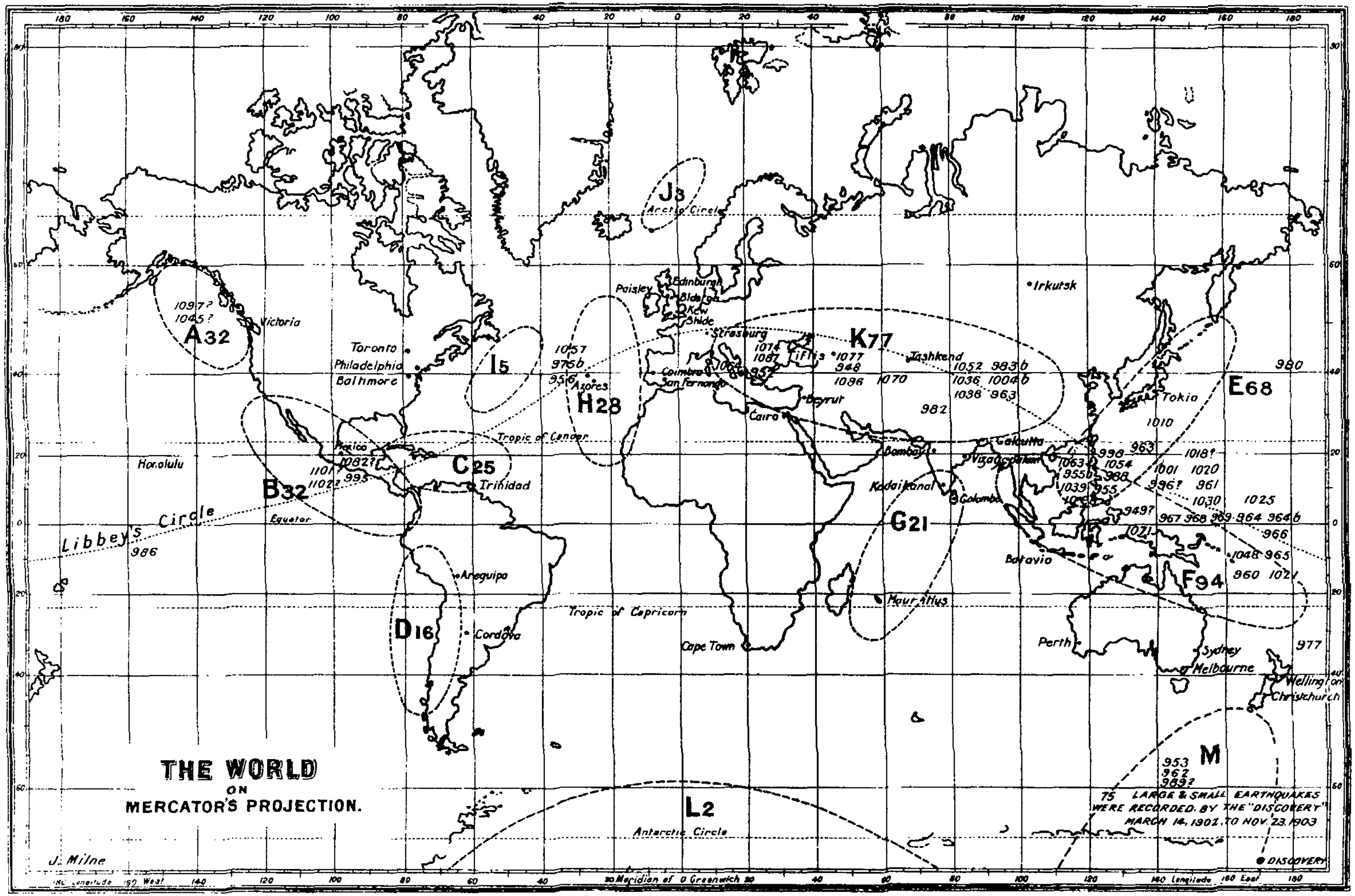
In registers from different stations in 1905, as in other years, the number of entries vary within wide limits. In the list for Shide there are 159 entries, but 47 of these refer to extremely minute displacements the nature of which is uncertain. Disturbances which are undoubtedly of seismic origin are therefore 112. Out of these 56 were distinctly megaseismic. On the accompanying map (Plate I.) the origins of 57 widespread movements are indicated. This number happens to be the annual average for the years 1899 to 1905 inclusive.

A glance at the map shows, with but few exceptions, that these earthquakes are confined to a circle passing from Central America through the Azores, the Alpine, Balkan and Himalayan ranges, into the East Indian Archipelago.

The quiescence of districts not lying on this band is very marked.

Destructive earthquakes occurred on April 4 in N.W. India, and on September 8 in Calabria. Whether the latter was in any way connected with the relief of volcanic stress which commenced in May 1905 and

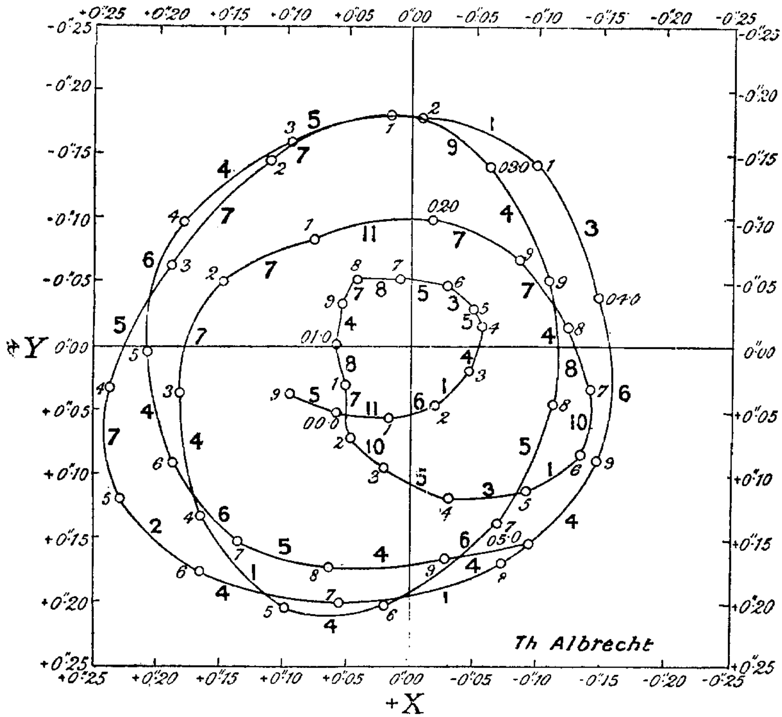
Earthquake districts are indicated A, B, C, &c., and the number of earthquakes which since 1899 have originated from these is expressed in large numerals. Origins for 1905 are indicated by their B.A. Shide Register number. Observing stations are named



Illustrating the Report on Seismological Investigations.

culminated in the violent eruptions at Vesuvius in April 1906 is a matter of conjecture. The largest earthquakes, eclipsing either of these, or the one of April 18, 1906, which devastated Central California, were numbers 1036 and 1052. They originated in Central Asia, one on July 9, and

FIG. 1.



the other on July 23, 1905. As accounts of destruction do not appear to have reached Europe, it may be assumed that the epifocal areas were only sparsely populated. The latter disturbance was felt in Tomsk, Kiachta, and other places.

IV. *Large Earthquakes in relation to Time and Space.*

Megaseismic motion has been automatically recorded since 1884.[1] Maps showing the origins of world-shaking earthquakes have been published in 'British Association Reports' since 1899. The last refers to the earthquakes of 1905, and is contained in this report. When, therefore, we are considering the time-relationship between earthquakes originating in different localities, the records at our disposal only extend over seven years. The material is admittedly as yet far too meagre to give satisfactory results, but, nevertheless, it is interesting to note the direction in which it points.

[1] *Seis. Soc. Trans.*, vol. x., p. 6.

In the following table megaseismic origins are classified under three heads :—

I. Refers to the East Pacific Coast north of the Equator, including the parallel Antillean Fold, shown on the map as District C.

II. Refers to the Western and South-Western portions of the North Pacific.

III. Refers to the folds extending from the Balkans to the Himalayas.

The first two divisions relate to earthquakes with a sub-oceanic origin, whilst the third relates to those which have originated in a continental area.

Districts	Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
							I.							
A, B & C	1899	3	6	1 or 2	1	0	0 or 1	3	0 or 1	7 or 10	0	2	1	24
"	1900	5	1	0	2	1	3	2	0	2	2	3	2	23
"	1901	3	1	2	1	2	0	0	0	0	4 or 5	0	3 or 4	16
"	1902	4 or 5	2	3	1	0	0	0	0	1	0	1	1	13
"	1903	3 or 4	2	2	2	0	1	0	1	1	0	0	0	12
"	1904	0	0	0	0	0	0	0	0	0	0	0	0	0
"	1905	0	0	0	0	1	0	1	0	0	1	0	2 or 3	5
Total Minimum		18	12	8	7	4	4	6	1	11	7	6	9	93
							II.							
E & F	1899	1	0	2	0	1	1	6	3	1	3 or 4	5	1	24
"	1900	3	0	2 or 3	1	1	1	1	5	3	2	2	0	21
"	1901	2	1	1	0	2	1	0	4 or 5	2 or 3	0	1	1	15
"	1902	6	2 or 3	3	0	2	1	1	2	2	0	3	0	22
"	1903	3	5	0	0	2	1	0	2	0	2	2	3	20
"	1904	2	0	0	1	2	4 or 6	3	2	1	2	2	1	20
"	1905	2	6	3 or 5	5	4	5	3	1	3	0	0	0	32
Total minimum		19	14	11	7	14	14	14	19	12	9	15	6	154
							III.							
K	1899	0	0	2	0	0	0	0	0	0	1	0	1	4
"	1900	0	0	1	0	0	0	0	0	0	0	0	0	1
"	1901	0	0	1	1	0	1	0	1	1	1	2	0	8
"	1902	0	1	2	0	2	1	2	6	2	1	1	2	20
"	1903	0	4	3	2	1	1	1	2	1	0	0	1	16
"	1904	0	0	1 or 2	2	0	0	0	0	0	0	0	0	3
"	1905	2	0	0	1	1	1	3	0	2	1	1	0	12
Total minimum		2	5	10	6	4	4	6	9	6	4	4	4	64
Total for all districts		39	31	34	24	22	24	26	31	29	20	25	19	324

If we take the months April to September as summer months, and October to March as winter months, we find the following numerical seasonal distribution :—

	Summer	Winter
N.E. Pacific	33	60
W. and S.W. Pacific	80	74
Balkan and Himalayan	35	29
Total	148	163

These epitomised results indicate that on the west side of the Pacific seismic frequency is greatest in summer, whilst on the eastern side it is greatest in winter.

Assuming the alternation in frequency in these two districts to be real, an explanation for the same may possibly be found in the seasonal alternation in the flow of ocean currents, the measured oscillations of sea-level, and the changes in the direction of barometric gradients—phenomena which are inter-related.

In summer-time off the coast of Japan the Kuro Siwo or Black Stream runs further northward in that season than in winter; while Dr. Omori tells us that although barometric pressure may be low at this time, this decrement in load is more than compensated for by the increased height in oceanic level.

For the third region the summer frequency for the land area is nearly identical with that of the West Pacific.

V. *Relationship of Large Earthquakes to each other and to Volcanic Eruptions.*

In any two districts, or in the same district, no apparent time-relationship between the occurrence of successive megaseisms has yet been formulated. If, however, we consider groups of large earthquakes which have occurred in a particular district, we may find a yearly decrease in their numbers, as in district A, while in districts like F and K there may be an increase. The time-relationship between after-shocks is well known. A striking illustration of the connections between a large earthquake and small shocks in a neighbouring district, together with displays of volcanic activity, occurred on January 31, 1906. On that date the coast of Colombia was inundated, islands sank at the mouth of the Esmeralda River, a cable was broken, and the volcano Cumbal erupted. These changes on the flanks of the Cordilleras were followed by disturbances in the Antilles.

Many small earthquakes occurred, and on February 16 several of them were sufficiently severe to damage masonry. Mount Pelée and La Soufrière showed signs of increased activity, and eight, if not nine, cable interruptions were recorded.

Here we have another illustration of the remarkable relationship which exists between the hypogenic activities of these parallel folds, a disturbance in one being accompanied or followed by a response in the other.[1]

VI. *Earthquakes and Changes in Latitude.*

The following table is a continuation of one published in the 'British Association Report,' 1903, pp. 78–80:—

Periods	1900	1901	1902	1903	1904
0–1, Jan. 1 to Feb. 5	11	8	11	9	3
1–2, Feb. 5 to March 14	6	7	7	7	1
2–3, March 14 to April 19	1	10	7	7	5
3–4, April 19 to May 26	4	5	4	5	4
4–5, May 26 to July 1	5	3	1	7	6
5–6, July 1 to Aug. 7	3	1	4	2	4
6–7, Aug. 7 to Sept. 12	5	10	6	4	6
7–8, Sept. 12 to Oct. 19	8	8	5	1	5
8–9, Oct. 19 to Nov. 24	7	7	4	4	4
9–10, Nov. 24 to Dec. 31	4	7	4	6	4

[1] See *Brit. Assoc. Rep.*, 1902, p. 73.

The numerals indicate the number of large earthquakes which occurred in successive periods of 36·5 days.

Two periods connected by brackets indicate times when the change in direction of pole-movement, as shown on Albrecht's figure, was comparatively rapid (see fig. 1).

If we compare the number of earthquakes which occurred in these selected periods with the total number of earthquakes which were recorded in equal intervals of time before and after the deflection periods we obtain the following results:—

													Comparable Totals
Earthquakes before deflection:	7	8	12	8	18	—	8	12	5	6	—	=	60
" during "	9	15	17	11	14	5	16	9	10	10	11	=	87
" after "	8	12	8	15	—	11	12	5	4	—	8	=	64

Omitting the four cases where figures for comparison are not complete, out of seven deflections there are six instances where the greater number of earthquakes have taken place during deflection periods.

If this result be added to that for the years 1892 to 1899[1] we see that out of twenty-three deflection periods there are eighteen instances where the greater number of earthquakes have been recorded for the deflection period. The totals for before, during, and after comparable deflection periods are respectively 167, 287, and 217, or as 1 : 1·72 : 1·29.

A closer determination of the possible relationship between pole-deflections and earthquake-frequency is obtained if the deflections between successive periods are expressed in angular measure. Such measurements have been made for each of the ten periods in the years 1899 to 1904. Opposite to each measurement figures give the number of earthquakes which occurred during the seventy-three days to which a measurement refers.

These have been divided into two groups. The first group embraces observations made in the years 1892 to 1899. During this interval the pole-path shows many irregularities.[2]

The second group refers to the periods between 1901(–6) and 1905(–0). During this interval the pole-path was comparatively regular (see fig. 1).

Group I.

Deflections	No. of Deflections	No. of Earthquakes	Average No. of Earthquakes	Group Averages
0° to 5°	1	18	18	—
5 " 10	7	153	22	—
10 " 15	8	32	4	6·9
15 " 20	4	13	3	
20 " 25	13	128	9	
25 " 30	10	185	18	14·5
30 " 35	9	115	13	
35 " 40	11	137	13	
40 " 45	5	67	13	17·7
45 " 50	6	115	19	
50 " 55	6	120	20	
55 " 60	2	42	21	—
60 " 75	5	122	24	—

[1] See *Brit. Assoc. Rep.*, 1893, p. 80.
[2] *Ibid.*, 1903, p. 80, fig. 2.

If we omit the first two entries in this table it appears that the average number of earthquakes in any period is approximately directly proportional to angular deflections of the pole-path during that period.

A similar result is shown in the three group averages which are given :—

Group II.

Deflections	No. of Deflections	No. of Earthquakes	Average No. of Earthquakes	Deflections	No. of Deflections	No. of Earthquakes	Average No. of Earthquakes
5° to 10°	1	8	8	30° to 35°	8	89	11
10 „ 15	2	33	16	35 „ 40	5	62	12
15 „ 20	3	39	16	40 „ 45	5	43	8
20 „ 25	2	18	9	45 „ 52	2	21	10
25 „ 30	13	134	10				

In this instance, where the path of the pole relatively to its mean position has been fairly uniform, earthquake-frequency does not appear to have been influenced.

VII. *On the Change of Level on two sides of a Valley.*

It has been found that under certain but frequently recurring conditions the two opposite sides of a valley move in opposite directions at the same time. On bright fine days the inclinations of the sides of a valley decrease. At night they increase. A valley may therefore be supposed to open and close. These conclusions, which do not necessarily apply to all valleys, are based on observations taken in two very different localities. The first were made in Tokyo, Japan, by means of horizontal pendulums giving continuous photographic records, installed on the two sides of a valley cut in alluvium.[1]

The second series were made on the two sides of a valley cut in chalk at Shide, near Newport, in the Isle of Wight. On the western side of the valley the instrument employed was an astronomical level reading to 1″·0 of arc. On the eastern side change of level was continuously recorded by a horizontal pendulum easily reading to 0″·5 of arc. Both were well founded and well protected from direct effects of solar radiation. When the instruments were side by side they gave similar and practically identical results.

The level, which was in charge of Mr. H. G. Morgan Hobbs, resident at Sunnyside, was read three times a day from July 26 to August 27, 1905. The difference between successive readings usually varied between 0″·5 and 3″·0, and with but few exceptions these readings indicated changes in level in opposite directions. During wet weather the diurnal movement was eclipsed by a rapid movement in a direction which corresponded with a closing of the valley. This sometimes amounted to 18″·0.

These diurnal changes in the vertical have been found in chambers excavated in rock, and at other installations when the daily change in temperature has not exceeded 2° F. They have been recorded in the New Red Sandstone at a depth of 19 feet. From these and other observations it is clear that they cannot be attributed to any warping effect in the instrument or change in temperature at the base of a pier on which an

[1] See *Brit. Assoc. Rep.*, 1895, p. 132.

instrument has been installed. They may, however, be due to the general warping of a district under the influence of solar radiation, or to the differential effects of loading and unloading of portions of the same. During the day the sides of a valley covered with vegetation lose load by evaporation and transpiration, and therefore underground drainage, tending to carry a water load to the bottom of a valley, is reduced. At night, with the cessation of these processes, the load at the bottom of a valley is increased. At that time streams and certain wells carry their greatest quantity of water. It is therefore at night that a valley may be expected to sag downwards, a suggestion that finds support in the observation that during wet weather, when we see streams in flood, the sides of the bounding valley approach each other in a marked manner.

The conclusion is that as the world turns before the sun its surface is measurably smoothed, whilst at night the frecklings on its face are measurably increased.

VIII. *Antarctic Earthquakes.*

From March 14, 1902, to December 31, 1903, a horizontal pendulum of the British Association type was installed in Victoria Land, about fifteen miles distant from Mounts Erebus and Terror. The instrument was in charge of Mr. Louis Bernacchi, who was attached to the s.s. 'Discovery.' Although observations were made under exceptional difficulties, Mr. Bernacchi brought back about 3,000 feet of photographic film. This was examined by your Secretary, Mr. Shinobu Hirota, and Mr. Howard Burgess of Newport. 'Preliminary Notes' on this analysis are to be found in the 'Proceedings of the Royal Society,' vol. A76, 1905, pp. 284-295. The more important results are as follows :—

1. Out of 136 records of earthquakes seventy-three refer to disturbances which originated in a sub-oceanic region between New Zealand and Victoria Land. In the British Association maps of Seismic Distribution this new district is indicated by the letter M. The greatest frequency was in the months April, May and June.

2. Certain earthquakes from district M have been recorded to the south-east by the 'Discovery,' and along a band about 20° in width towards the north-west as far as Britain. This phenomenon of recordable motion being propagated in one direction only round the world is now known to be true for earthquakes originating in other districts.

3. An earthquake may be recorded at stations near its origin and its antipodes, but not at intermediate stations.

4. As an earthquake radiates, the phase of motion which travels the greatest distance is that of the largest waves or P_3.

5. The average arcual velocity for P_3 is approximately 3 Km per second, with a possible acceleration in the quadrantal region of its path, where it may reach 4 Km per second.

6. Other results refer to slow changes in the vertical, diurnal waves, tremors and pulsations.

IX. *Note on the Determination of the Time of Origin of Earthquakes.* *By* R. D. Oldham.

One of the greatest desiderata in the study of the nature and propagation of earthquake waves is an exact determination of the time of origin of the earthquake. Few are the instances where a great earthquake occurs in countries sufficiently civilised to allow of an accurate determination by direct observation, more frequently we have one or two instrumental records at distances of a hundred to a thousand miles from the origin, and the results obtained from the study of individual earthquakes have so far been too discordant to enable these to be used with certainty. Recently Professor Imamura has published a memoir 'On the Transit Velocity of the Earthquake Motion originating at a Near Distance,'[1] which should be of assistance, but, owing to the mode of discussion adopted, his results are not directly applicable for the purpose in hand. As, however, all the data are published in detail, I have been able to plot them on squared paper and obtain two time-curves from which the intervals tabulated below were measured.

Table showing the intervals taken by earthquake waves to travel from their origin to distances up to 10° (1111·1 kilometres) deduced from the records of twenty-four Japanese earthquakes.

Distance in Degrees	Commencement of Preliminary Tremors				Commencement of Principal Portion	
	Interval	Diff.	Interval	Diff.	Interval	Diff.
	M. S.	S.	M. S.	S.	M. S.	S.
1	0 21		0 29		0 29	
		18		24		29
2	0 39		0 53		0 58	
		18		18		29
3	0 57		1 11		1 27	
		18		15		29
4	1 15		1 26		1 56	
		15		13		29
5	1 30		1 39		2 25	
		9		12		30
6	1 39		1 51		2 55	
		11		10		29
7	1 50		2 1		3 24	
		10		8		29
8	2 0		2 9		3 53	
		12		6		29
9	2 12		2 15		4 22	
		6		3		29
10	2 18		2 18		4 51	

Two groups of times were dealt with, P_1 and P_3 of Japanese seismologists. The first of these represents the commencement of the preliminary tremors, and two columns are devoted to it in the table : the first represents the measurements of a curve drawn so as to average the records at each distance most closely. It is convex upwards, indicating a slower rate of propagation as the epicentre is neared, but the irregularity of the differences of time for equal differences of distance suggests that it departs from the true time-curve. Another curve was accordingly drawn, representing the average of the observations almost as well as the first, while the more regular decrease in the differences, as seen in the second column, indicates that it is a closer approximation to the true curve than the other. Both columns give unduly high rates of transmission at the longer distances, the curves being uncertain, beyond 7°, from paucity of records.

[1] *Publications of the Earthquake Investigation Committee in Foreign Languages*, No. 18, Tokyo, 1904.

The second group of times dealt with is the P_3, or commencement of the principal portion of the disturbance. These records group themselves most satisfactorily along a straight line, representing a rate of transmission of about 29·1 seconds per degree of arc. Professor Imamura does not record the time of maximum, but this would be later by about five or six seconds per degree. Probably 35 seconds per degree represents very closely the true rate of propagation.

It must be remembered that only four out of the twenty-four earthquakes dealt with originated on, or so near, land that the place and time of origin could be determined with accuracy by direct observation. The other twenty originated under the sea, and their time and place of origin had to be inferred, with a consequent liability to error in each case; but these errors probably compensate each other to a great extent, and, used with judgment, it is believed that the table will prove useful.

X. *Diurnal Changes in Level at the Royal Alfred Observatory, Mauritius.* *By* T. F. CLAXTON.

A Milne seismograph for recording unfelt earth-tremors has been in use at the Royal Alfred Observatory, Mauritius, since September 1898. It was first mounted in a small wooden hut, 12 feet square by 18 feet high, on a *brick* pillar built up from a concrete floor 9 inches thick; but it was found that with this mounting a very large diurnal inequality of level was recorded, a daily range of 8″ being of frequent occurrence, and during heavy rains the boom occasionally drifted off the sheet.

A more substantial foundation was constructed in November 1899. The pillar was removed, and a hole dug 6 feet deep by 4 feet square; this was filled up with 4 feet of concrete, and a tapering column built up from the latter without touching the earth on any side.

In addition to the wanderings of the boom due to unstable mounting, the registers are vibrated at night and early morning by tremors, which appear to be due to radiation from the concrete pillar, the tremors being most active during rapid cooling. In order therefore to decrease the daily range of temperature within the hut in the month of March 1900, the latter was completely enclosed by a straw thatching at a distance of 3 feet from the walls and roof; but this did not entirely destroy the tremors, and the nocturnal radiation was further checked by means of a lamp which, lighted before sunset and extinguished soon after sunrise, has remedied this defect, but has unfortunately introduced another.

For the study of the diurnal and secular change of level a second pendulum, registering N.–S. tilting, was added to the instrument in February 1904,[1] and a preliminary discussion of its records revealed a well-marked tilt to south, commencing at the time of lighting the lamp.

It is not easy to distinguish the effect of the lamp on the E.–W. boom, as the turning-points occur at about the times of lighting and extinguishing the lamp. The effect, if any, would be to acccelerate both morning and afternoon turning-points, as the boom is at its most easterly position when the lamp is lighted, and most westerly when the lamp is extinguished. In the E.–W. records, as affected by the lamp, the afternoon turning-point

[1] This pendulum registers on the same cylinder as the E.–W. pendulum, with which its booms run parallel. The discs at the end of the booms have been reduced in width to 15 mm. Silk threads stretched across the registering slit at every second millimetre produce a fine scale on the paper, by means of which the hourly ordinates are readily and accurately measured.

occurs two hours later than in the N.–S. records, occurring in the latter about two hours before the lamp is lighted.

It appears from the above that with the seismograph exposed to the ordinary diurnal range of temperature the registers are affected either by air tremors or by the lamp introduced to check them. For this reason, in the month of July 1904 the instrument was removed to the magnetic basement, in which the diurnal range of temperature is seldom greater than 0°·2 (Fahrenheit), the chamber having double walls, with an eighteen-inch air-space between them, and its floor being 12 feet below the surface of the ground. The chamber is ventilated by means of a 12-inch pipe laid at a depth of 11 feet below the surface of the ground, and communicating with the air at a point 35 yards distant. A hole was dug, 10 feet deep by 3 feet square, and filled up with 7 feet of concrete, on which a tapering column, also of concrete, was built up to a height of 3 feet above the floor for the reception of the seismograph.

The registers obtained with this installation show no air tremors whatever. No measures have yet been made, but from an examination of the photographs it would appear that the character of the diurnal inequality of level has altered considerably. Its amplitude is very much less than formerly, and the maximum tilt to east occurs at about 8h. in place of at 17h., and the maximum northerly tilt at about 17h. in place of at 6h.

The accompanying vector diagram (fig. 2) shows the mean diurnal tilt of the boom for the year 1903, as determined from the hourly measures of the north and east components. The effect of lighting the lamp (at about 5½h. P.M.) is to tilt the pillar towards the south, and thus reverse the northerly tilt, which sets in after 14h., and to form a closed loop, but there is no corresponding tilt to north when the lamp is extinguished at 6 A.M., the boom tilting steadily towards the south-east until 2 P.M.

FIG. 2.—*Mean Diurnal Inequality of Level at the Royal Alfred Observatory, Mauritius, in the year* 1903. (*Mauritius Civil Time.*)