# *Seismological Investigations.—Third Report of the Committee, consisting of* Mr. G. J. SYMONS (*Chairman*), Dr. C. DAVISON *and* Mr. JOHN MILNE (*Secretaries*), Lord KELVIN, Professor W. G. ADAMS, Professor T. G. BONNEY, Dr. J. T. BOTTOMLEY, Mr. C. V. BOYS, Sir F. J. BRAMWELL, Mr. M. WALTON BROWN, Professor G. H. DARWIN, Mr. HORACE DARWIN, Major L. DARWIN, Mr. G. F. DEACON, Dr. G. M. DAWSON, Professor J. A. EWING, Professor C. G. KNOTT, Professor G. A. LEBOUR, Professor R. MELDOLA, Professor J. PERRY, Professor J. H. POYNTING, Dr. ISAAC ROBERTS, *and* Professor H. H. TURNER. *Drawn up by Secretary*, JOHN MILNE.

CONTENTS.



## I. *Progress made towards the Establishment of Earthquake-observing Stations in various Parts of the World.*

IN the report for 1897 there will be found a copy of a circular inviting co-operation in the establishment of a seismic survey of the world, which, with the kind assistance of the Foreign, Colonial, and India Offices, was forwarded to many countries and colonies. The result of these communications, together with private correspondence, has been to establish or arrange for the establishment of instruments at twenty-two stations.

The following notes indicate the position we hold in regard to these stations, and the direction in which further co-operation may be expected.

The instruments at Shide, in the Isle of Wight, are indicated as Nos. 1 and 2, but it is only No. 1 that is of the type recommended by this committee. No. 2 consists of a pair of horizontal pendulums writing on smoked paper. Both were purchased by Government grants from the Royal Society.

N 2

1. *Canada: Toronto. Meteorological Observatory.*
Professor R. F. STUPART, *Director.*

The instrument (No. 3) reached this station during the meeting of the British Association in August, 1897, when arrangements were made for its installation in a small building outside the Magnetic Observatory. It has already yielded several good seismograms, the most important being that of a West Indian earthquake on December 29. This and other disturbances were also recorded in the Isle of Wight, and are described in this report. Much trouble was occasioned by the frequency and magnitude of 'tremor' storms, especially on frosty nights. Although the marked character of these was reduced by copious ventilation, Professor Stupart writes me that with the hope of getting rid of them altogether he intends to move the instrument inside the main building of the observatory.

This instrument was provided by the Meteorological Observatory, Toronto.

2. *U.S.A.: Cambridge, Mass. Harvard University.*—Professor E. C. PICKERING.

This instrument (No. 4) was shipped from London in September, 1897. On April 13, 1898, Professor Pickering wrote that the instrument, which was purchased by the Harvard University, is to be shipped to their observatory in Peru.

3. *India: Madras. Nungumbaukum. The Astronomical Observatory.*
Dr. MICHIE SMITH.

This instrument (No. 5), after being tested in the Isle of Wight, was delivered at the India Stores in October, 1897. It is now in Madras. It was provided by the Indian Government.

4. *Spain: Cadiz. San Fernando. Instituto y Observatorio de Marina.*
Captain J. VINIÈGRA.

For this instrument (No. 6) the thanks of our committee are due to Mr. R. K. Gray, at whose expense it was constructed. It was shipped in December, 1897, and Captain Viniègra has sent a sample of its records, together with a plan of the observatory, showing the position in which it is installed.

5. *U.S.A.: Philadelphia, Penn. Strathmore College.*
Professor S. J. CUNNINGHAM.

This instrument (No. 7) was constructed at the expense of Mr. Joseph Wharton, 206 Philadelphia Bank Building, Philadelphia, and presented by him to the above institution.

It was shipped from here in November, 1897.

Mr. Wharton very kindly offers further co-operation in the work of this committee.

Professor Cunningham has written describing the installation.

6. *Japan: Tokio. Imperial University.*—Dr. F. ŌMORI.

In a despatch, dated November 22, 1897, Her Majesty's Minister, Sir Ernest Satow, has the honour to inform Lord Salisbury that he communicated with the Japanese Government respecting our circular to which a reply was received from Baron Nishi to the effect that the authorities concerned have decided to co-operate with the British Association.

The instrument (No. 8) was shipped in February, 1897.

7. *England: Surrey. Richmond, Kew Observatory.*—Dr. CHARLES CHREE, *F.R.S.*

The instrument (No. 9) was delivered on March 8, 1898. It was purchased by the Kew Committee, and is now in operation.

8. *Canada: British Columbia, Victoria.*—E. BAYNES REED.

The instrument (No. 10) was sent on March 21, 1898, to the care of Professor Stupart, who will see to its installation. It was paid for by means of the British Association grant given in Toronto, 1897.

9. *Java: Batavia. Magnetisch en Meteorolgisch Observatorium.*
J. P. VAN DER STOK, *Director.*

This instrument (No. 11) was shipped May 1, 1897. It was purchased by the Dutch Government.

10. *Africa: Cape Town. The Observatory.*—D. GILL, *F.R.S., Director.*

On March 19, 1897, Dr. Gill placed our circular before the Admiralty recommending that co-operation be granted. He also pointed out to the Lords Commissioners of the Admiralty that the British Association Committee undertook the labour and cost of discussing results. The instrument (No. 21) was purchased by Her Majesty's Government.

11. *South America: Argentina. Cordova. The Observatory.*
W. G. DAVIS, *Director.*

In November last, after showing Mr. Davis seismograms, he visited Mr. Munro's workshop, where he ordered an instrument. This instrument (No. 14) was shipped from London on May 13, 1898.

12. *India: Bombay. Colaba. The Magnetic and Meteorological Observatory.*
N. A. F. MOOS, *Director.*

The orders for instruments to be established at Bombay and Calcutta originated through a letter of recommendation from the Government of India, Department of Revenue and Agriculture, dated October 7, 1897, addressed to Her Majesty's Secretary of State for India.

13. *India: Calcutta. Alipore. Meteorological Observatory.*
(See Note relating to the Bombay Instrument.)

These instruments (Nos. 12 and 13), which were purchased by the Indian Government, were delivered at the India Stores on April 27, 1898.

14. *Mauritius: Royal Alfred Observatory.*—T. F. CLAXTON, *Director.*

On April 29, 1897, Mr. Claxton wrote that if our committee were prepared to grant 25*l.* towards an instrument he might spare 25*l.* from the Government Grant for 1898. Mr. Claxton's offer was accepted, and the instrument (No. 17) was despatched in July, 1898.

15. *New Zealand: Wellington.*—Sir JAMES HECTOR, *F.R.S.*

Sir James Hector referred our circular to the New Zealand Government, who agreed to ask Parliament for the necessary grant to purchase instruments. On July 30, 1897, Sir James ordered two instruments (Nos. 16 and 20). The former of these was despatched in June, and the latter was despatched on August 31, 1898.

16. *Egypt: Cairo. Abbasieh. The Observatory.*

Mr. W. J. Wilson, Inspector-General of Irrigation for Upper Egypt, forwarded to the Ministry of Public Instruction our circular, with the result that H.E. Yacoub Artin Pasha, Under-Secretary of State for Public Instruction, directed that an instrument should be supplied to the above observatory. This (No. 22) will be despatched in September, 1898.

17. *Scotland, Paisley. The Coats Observatory.*

The Rev. Andrew Henderson, Chairman of the Coats Observatory Committee, kindly brought our circular to the notice of that body, with the result that an instrument (No. 18) was ordered on February 21, 1898. It was sent to Paisley in July.

18. *Mexico.*

On May 25 C. Romero, Esq., Acting Chargé d'Affaires at the Mexican Legation, 87 Cromwell Road, London, wrote the Chairman of our committee that he was carrying out instructions received from the Minister of Encouragement (Fomento) of the Mexican Government to purchase a horizontal pendulum. This instrument (No. 19) was despatched on August 15.

19. *Syria: Beyrout. Protestant College.*—Professor R. H. WEST, *Director.*

On the recommendation of Professor R. H. West an instrument (No. 15) was ordered for the observatory at the above college. It was despatched in June, 1898. Professor West says that all records will be at our disposal.

20. *U.S.A.: Washington, D.C. Coast and Geodetic Survey.*
W. W. DUFFIELD, *Superintendent.*

Mr. Duffield wrote on July 16, 1897, that to take up the work proposed would need special authorisation and consequent provision of means. He would send copies of our circular to the United States Naval Observatory, Dr. J. G. Porter, Director of the Cincinnati Observatory, and to the Director of the Lick Observatory.

21. *U.S.A.: Washington, D.C. U.S. Naval Observatory.*
Professor WM. HARKNESS.

On July 19, 1897, Professor Harkness wrote saying that he hoped in the not distant future conditions may present themselves enabling him to co-operate.

22. *S.A.: Colombia, Bogota.*

A despatch, dated August 12, 1897, from Montagu Villiers, Esq., British Vice-Consul at Bogota, to the Marquis of Salisbury stated that the Director of the National Observatory at Bogota hoped before long to purchase the necessary instrument and co-operate in the work of our committee.

23. *Australia: Sydney. The Observatory.*—H. C. RUSSELL, *F.R.S., Director.*

Mr. Russell regretted that, owing to want of funds, he was unable to take a share in the work. He will let us know whether his own pendulum is of any use.

24. *China: Shanghai. Zikawei Observatory.*—L. FROC, *S.J.*

On April 5, 1897, Father Froc wrote regretting that he had neither the means nor the facility to establish an instrument at Zikawei, at which place, he states, the most severe shocks originating in Japan are not experienced.

25. *Malta: Gozo. The College.*—Rev. JAMES SCOLES, *S.J.*

Father Scoles, writing from Beaumont College, Old Windsor, said: 'No doubt some interesting results would be obtained in Malta, but in the College there no one has sufficient leisure to attend to such a work, nor are there any funds available.'

26. *Spain: Cadiz.*—W. G. FORSTER.

Mr. Forster would like an instrument were he at a more favourably placed station, but not where he is.

27. *Brazil: Rio de Janeiro. The Observatory.*—THE DIRECTOR.

On April 20, 1897, the Director of this observatory wrote that he had received through Her Majesty's Minister, Sir Edmund Constantine Henry, the circular issued by this committee. Last June a similar proposal had been received from Dr. Gerland, of Strassburg, to which he had replied favourably. Because nothing further had been heard from Dr. Gerland, the observatory at Rio was prepared to undertake the observations we proposed. The letter concludes with instructions respecting payment for the instrument.

On Jan. 20, 1898, the Foreign Office forwarded to me the translation of a note which Her Majesty's Minister at Rio de Janeiro had received from the Brazilian Government, from which it appears that they are not disposed to co-operate in the scientific observations indicated by this committee.

28. *Hawaii: Honolulu.*—W. J. KENNY, *Her Majesty's Acting Commissioner and Consul-General.*

Shortly after the death of Commissioner Hawes, Mr. T. R. Walker, Acting British Consul-General, placed our circular before Professor W. D. Alexander, who wrote on July 16, 1897, that the proposed station would have to be established in connection with the Hawaiian weather service or at Oahu College, but at present he did not think that the necessary funds were available. The subject should be taken into consideration by the next legislature.

On December 27 Commissioner W. J. Kenny wrote suggesting that seismological investigations be taken up in Hawaii, and if I could send a seismograph he would see to its installation and working.

29. *Physikalisches Central Observatorium.*—Admiral RYKATCHEFF. *Wass.-Ostr., 23 Linci Haus No. 2, 12/24, February,* 1898. *St. Petersburg.*

The Russian Meteorological Office think of establishing two instruments of the type recommended by the Seismological Committee of the British Association. It would, however, be first necessary to obtain the opinion of the directors of observatories where the instruments might be installed. Copies of instructions respecting the working of the instruments were required.

Three copies of instructions were forwarded to St. Petersburg on March 3, 1898.

30. *Kaiserliche Akademie der Wissenschaften, Wien. March* 5, 1898.

The earthquake commission of the above Academy inquired respecting the cost of a seismometer.

I replied stating the price of instrument and its accessories, gave the address of the maker, and sent the Toronto Report for 1897.

31. *Australia: Melbourne. The Observatory.*—P. BARACCHI, Esq.

The Director of the above observatory wrote on February 1, 1898, in reply to the circular issued by our committee that he had applied to the Victorian Government to take part in our work, and had laid the matter before Section A of the Australian Association for the Advancement of Science. It is hoped that co-operation may be extended to us in the early future.

The following abstract of a report of the Seismological Committee of the Australian Society for the Advancement of Science is taken from 'Symons' Monthly Meteorological Magazine,' March 1898, p. 26 :—

'*Seismological Committee.*

'This report was presented by the Secretary, Mr. George Hogben, M.A., of Timaru, New Zealand, and stated that the most interesting result of the labours of the observers was the fact, based upon rough calculations, that the great South Australian earthquake of May 10, 1897, proceeded from a line parallel to the coast near Beachport and Kingston, and was possibly due to a sliding of one part of the crust upon another, such as forms what is called in geology a "fault." This was probably deep, but the later and slighter shocks were surface ones, caused by readjustments of the immediate crust. The subject was still under investigation by the Secretary. But Mr. Hogben pointed out that it was as part of a world-system of seismological observations that the work of the Committee might be most useful. An international seismological committee had been set up, embracing all the ablest workers in every part of the world, and in co-operation with that committee were committees of the British Association and of the Royal Society. They desire especially to be able to track the microseismic vibrations or minute earthquake waves, which travelled from the sources of disturbance all round the earth's surface, or it might be right through the solid mass of our world (if it is solid). The speed of these finer waves was many times greater than that of the larger waves felt by us, reaching a velocity as great as 12 miles per second, or even more. For the purpose of observing them the international committee had agreed upon a certain type of instrument—the horizontal pendulum—

to be used by all stations alike, as it was important that instruments of the same kind and of the same degree of sensitiveness should be employed for purposes of comparison.'

#### 32. *Norway: Hammerfest.*

Dr. F. Nansen very kindly offered his co-operation in an endeavour to establish the station 'farthest north.'

#### 33. *Ireland: Dublin.*

Professor W. F. Barrett is actively endeavouring to establish a station in Ireland, towards which I understand that Lord Ardilaun has given substantial support.

It is interesting to note that this co-operation, and that referred to in notes (4) and (5), followed lectures bearing on a seismic survey of the world.

## II. *Notes on Special Earthquakes.*

#### 34. *Foreign, Colonial, and Indian Offices.*

I was able to inform the Foreign and Colonial Offices that the official notification stating that there had been interruption of two West Indian cables connecting us with Venezuela on December 31 probably referred to the effects of a submarine earthquake, which happened at 11.30 A.M. on December 29 (see p. 214). I received letters of thanks for the information, the correctness of which was not confirmed until March 1.

From the Foreign, Colonial, and Indian Offices I have received many communications relating to the establishment of instruments abroad and other matters connected with the work of this committee. These are referred to under other sections.

#### 35. *Correspondence respecting Earthquakes in the West Indies.*

Mr. Secretary Chamberlain directed that the following two despatches should be sent to me, adding that if I were disposed to interest myself in the matter he would take steps to obtain information on points about which it might be deemed worth while to make inquiry. The first despatch is from the Governor of the Leeward Islands, and the second from the Administrator of Montserrat:—

Springfield House, St. Kitts:
February 28, 1898.

SIR,—I have the honour to transmit to you the duplicate of a despatch from the Commissioner of Montserrat reporting that several severe shocks of earthquake have recently occurred in that island, which have caused considerable damage to buildings, although it does not appear that any lives have been sacrificed.

2. Mr. Baynes remarks in paragraph 5 of his despatch that these shocks of earthquake have been of frequent occurrence since the floods of November, 1896; a fact to which I have had occasion to refer in previous correspondence.

3. What has caused this to be the case I am not prepared to say; but I agree with Mr. Baynes that the subject is one of peculiar interest, and I should be glad if it could form the subject of scientific investigation.

I have, &c.,
F. FLEMING.

The Right Hon. JOSEPH CHAMBERLAIN, M.P., P.C.

Commissioner's Office, Montserrat:
February 21, 1898.

SIR,—On Tuesday, the 15th instant, severe shocks of earthquake occurred in this island, which have since been followed by shocks of nearly equal severity, and have caused considerable damage to buildings.

2. The principal shock was at 11.16 A.M. on Tuesday, and was the most severe I have ever experienced. This was followed by shocks so numerous as to seem almost continuous until 3.45 P.M., when there was one of equal severity but shorter duration; and during the rest of the day and the following night numerous shocks continued to be felt. On Friday, at 7 A.M. and 4.25 P.M., and on Sunday, at 9.20 A.M., very severe shocks occurred, and in the intervals minor shocks have been of constant occurrence.

3. The windmill tower at Gage's Estate has been seriously damaged, and the chimneys on the Grove, Dagenham's, Weeke's, Gage's, Paradise, and White's Estates have sustained injury. One house at Gage's has been so much damaged as to be made uninhabitable, and several houses in various localities have been injured. St. George's Church and St. Anthony's Church and Rectory have also sustained some damage.

4. The only serious damage to any Government building has been at the Poor House, where the walls of a small detached building have been so seriously damaged that it has been necessary to remove the inmates. There are cracks in the walls of the Court House and Treasury, but these appear to be superficial. On the public roads, especially those of recent construction, large quantities of earth and boulders have been shaken from the cliffs on to the roadway, but no further damage is reported. Several breaks in the water pipes supplying the town occurred through landslips in the ravines through which the pipe track passes, but these injuries were at once repaired.

5. These shocks of earthquake have been of frequent occurrence since the flood of November, 1896, and in my letter of May 3 last I gave some account of them up to that date. Of late they have greatly increased in severity. Some months ago a number of shocks occurred in Guadeloupe, but I have no recent information from that island. With this exception they have not been felt in the neighbouring islands. They would therefore appear to be of local origin, and some disturbance of the volcanic springs in Gage's Mountain has evidently taken place. The subject is one of peculiar interest, and seems to be well deserving of scientific investigation.

I have, &c.,
EDWARD BAYNES,
Commissioner.

His Excellency Sir F. FLEMING, K.C.M.G.

The following two letters bearing on the same subject are also of interest:—

Richmond Hill, Montserrat, West Indies:
March 2, 1898.

DEAR SIR,—I beg to inform you that since the flood of November 29, 1896, which caused great injury to life and property in this island, innumerable shocks of earthquake have been experienced.

There are in this island several craters and sulphur springs, and there are also a few hot-water springs, all of which go to prove that the volcanoes here are by no means extinct, and it is thought by some persons that the mouth of one of the numerous craters has been filled up by a landslip caused by the above-mentioned flood, on the night of which there were several shocks of earthquake—the first experienced in Montserrat for a great number of years. It is possible that the filling up of this crater has been the cause of all the earthquakes we have been feeling here lately.

Since November 1896 there have been experienced at least one thousand shocks of earthquake.

The most severe shocks took place on the following dates:—November 29, 1896; April 22, 24, 25 and 29, 1897; July 28, 1897; December 4, 1897; February 15, 18 and 20, 1898. Those on February 15 exceeded all the others in point of severity. Some persons state that there were eighty-one shocks that day, of which forty-one were felt in three hours.

The shock on April 29, 1897, though one of the longest, was felt throughout this portion of the West Indies, but was of slight force, and, notwithstanding its very long duration, did no injury here, though a great deal of damage was done at Pointe-à-Pitre, in the neighbouring French island of Guadeloupe.

All the other earthquakes have been entirely local, having not even been noticed at Antigua, an island about thirty miles away, though those in April were felt at the isolated rock of Redonda, a few miles off the north coast of this island.

Only the most severe earthquakes have been mentioned above; but scarcely a day passes without our feeling a few shocks, and excluding February 15 as many as thirty shocks have been felt in one day.

During the last month or two the smell of sulphur from the craters has been very strong and disagreeable, silver tarnishing in town very easily.

All the earthquakes seem to have had the same direction, viz., from 'Gage's' Mountain, where the Soufrière is located (see Admiralty Chart of Montserrat), with the exception of that of April 29, which appeared to come from the direction of Guadeloupe, viz., the south.

I am thankful to say that the shocks are usually of very short duration, averaging four or five seconds.

Some of the oldest inhabitants of the island affirm that the worst shock, on February 15 (11.16 A.M.), was just as *severe* as the great earthquake of 1843, but being of shorter duration did not do so much damage.

Several buildings have been very badly damaged. Innumerable cracks have appeared in nearly every stone building in the island, including the Court Hall and the churches.

These shocks of earthquake, which have been continually felt for the last sixteen months (*i.e.* since November 1896), are causing great anxiety among the inhabitants, and it is not known but that they may culminate either in a volcanic eruption or the numerous stone buildings, weakened as they already are by these continual shocks, must in course of time be thrown to the ground unless the earthquakes cease.

The whole subject seems well deserving of scientific investigation. The Government of the island is in a very bad financial state, and could not afford any pecuniary aid to an investigation, though it would doubtless give as much encouragement as possible to the investigators; but probably in the interests of science your committee or some other scientific society would bear the expense of making a scientific investigation which would be most interesting to science in general.

Official reports in connection with the recent earthquakes have doubtless been sent to the Secretary of State for the Colonies, and I would suggest your communicating with the Colonial Office in considering the question; but if your Society cannot send out a scientist I should be glad if the substance of this letter could be published in the English newspapers, and perhaps some scientist would take the matter up.

I am, dear Sir, yours faithfully,
H. DE COURCY HAMILTON,
Fellow of the Royal Colonial Institute.

JOHN MILNE, Esq., Secretary, Seismological Investigation Committee, London.

*Extract from Letter of Joseph Sturge, Esq., Wheeley's Road, Birmingham, dated February* 3, 1898.

'I think you may be glad to know of a somewhat curious phenomenon that has taken place in a small island in the West Indies, Montserrat, with which I am connected.

'The island is the tip of a submarine mountain: it is 12 miles long by 7 wide, and 3,000 feet high. The sea is 2,000 fathoms deep all round the island. There are sulphureous springs of hot water which emit vapour, but no more active volcanic action, and for forty years there have been no serious earthquakes and very few noticeable ones.

'On November 29, 1896, there was an extraordinary rain-storm, 20 inches of rain falling in the centre of the island in about twelve hours. Since that time the island has been subject to constantly recurring slight shocks of earthquake. They come almost every day, and sometimes several in a day. They do not do much harm, but keep people more or less in a state of alarm, and the curious problem is what happened on the day of the rain-storm that *set the earthquakes going.*

'The sulphur springs have emitted a much more copious volume of gas since the change, so that silver now goes black three miles off.

'It may be worth while to mention that in 1880 there was a similar flood in the neighbouring island of St. Kitts, and that the same night there was a volcanic disturbance in Dominica (150 miles from St. Kitts), and a boiling lake came into existence among the mountains there.'

On April 15 Mr. Sturge writes that the earthquakes increased in frequency and violence until the end of February. Almost all stone buildings were more or less injured. Since then there has been a great drought, coincidently with which the shocks have almost entirely ceased. Is this a *propter hoc* or only a *post hoc*?

III.—*Catalogue of Earthquakes recorded by a Gray-Milne Seismograph at the Central Meteorological Observatory, Tokio, December* 17, 1897, *to January* 27, 1898. (*Continuation of Catalogue commencing in the British Association Report*, 1886.

| No. | Month | Day | Time | Duration | Direction | Maximum Period and Amplitude of Horizontal Motion | | Maximum Period and Amplitude of Vertical Motion | | Nature of Shock |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | secs. | mm. | secs. | mm. | |
| | | | | | **1896.** | | | | | |
| | | | H. M. S. | M. S. | | | | | | |
| 1,816 | XII. | 17 | 1 17 25 A.M. | 0 47 | S.S.E., N.N.W. | 0·2 | 1·9 | 0·2 | 0·4 | quick |
| 1,817 | ,, | 17 | 6 14 06 P.M. | — | — | — | — | — | — | slight |
| 1,818 | ,, | 20 | 5 03 38 A.M. | — | — | — | — | — | — | ,, |
| 1,819 | ,, | 29 | 7 06 06 A.M. | — | — | — | — | — | — | ,, |
| | | | | | **1897.** | | | | | |
| 1,820 | I. | 8 | 5 57 25 A.M. | — | — | — | — | — | — | slight |
| 1,821 | ,, | 9 | 9 27 18 A.M. | — | — | — | — | — | — | ,, |
| 1,822 | ,, | 13 | 6 39 39 A.M. | — | — | — | — | — | — | ,, |
| 1,823 | ,, | 16 | 10 58 52 A.M. | — | — | — | — | — | — | ,, |
| 1,824 | ,, | 17 | 0 49 28 A.M. | 3 32 | N.E., S.W. | 0·7 | 4·0 | 0·2 | 0·3 | clocks stopped, slow |
| 1,825 | ,, | 17 | 5 36 36 A.M. | — | — | — | — | — | — | slight |
| 1,826 | ,, | 18 | 9 27 03 P.M. | — | — | — | — | — | — | ,, |
| 1,827 | ,, | 20 | 10 46 22 A.M. | — | — | — | — | — | — | ,, |
| 1,828 | ,, | 23 | 2 12 42 P.M. | — | — | — | — | — | — | ,, |
| 1,829 | ,, | 25 | 1 48 55 P.M. | — | — | — | — | — | — | ,, |
| 1,830 | ,, | 27 | 3 46 38 P.M. | — | — | — | — | — | — | ,, |
| 1,831 | II. | 1 | 10 33 35 P.M. | — | — | — | — | — | — | ,, |
| 1,832 | ,, | 4 | 2 13 46 P.M. | — | — | — | — | — | — | ,, |
| 1,833 | ,, | 4 | 3 51 56 P.M. | — | — | — | — | — | — | ,, |
| 1,834 | ,, | 7 | 4 38 33 P.M. | 5 47 | N.W., S.E. | 0·7 | 1·7 | — | — | weak, slow |
| 1,835 | ,, | 8 | 5 25 17 A.M. | — | — | — | — | — | — | ,, |
| 1,836 | ,, | 8 | 8 07 51 A.M. | — | — | — | — | — | — | ,, |
| 1,837 | ,, | 9 | 10 1 35 P.M. | — | — | — | — | — | — | ,, |
| 1,838 | ,, | 11 | 0 52 18 A.M. | — | — | — | — | — | — | ,, |
| 1,839 | ,, | 11 | 7 24 12 A.M. | — | — | — | — | — | — | ,, |
| 1,840 | ,, | 13 | 2 19 11 A.M. | — | — | — | — | — | — | ,, |
| 1,841 | ,, | 17 | 9 13 56 P.M. | — | — | — | — | — | — | ,, |
| 1,842 | ,, | 18 | 8 11 30 P.M. | — | — | — | — | — | — | ,, |
| 1,843 | ,, | 20 | 9 52 28 P.M. | — | — | — | — | — | — | ,, |
| 1,844 | ,, | 21 | 0 04 17 P.M. | — | — | — | — | — | — | ,, |
| 1,845 | ,, | 28 | 1 14 58 A.M. | 2 22 | N.N.W., S.S.E. | 1·4 | 3·1 | 0·4 | 0·2 | ,, |
| 1,846 | III. | 5 | 1 14 20 P.M. | — | — | — | — | — | — | ,, |
| 1,847 | ,, | 5 | 5 27 41 P.M. | 0 37 | S.W., N.E. | 0·2 | 0·6 | 0·1 | 0·1 | quick |
| 1,848 | ,, | 6 | 5 36 12 A.M. | — | — | — | — | — | — | slight |
| 1,849 | ,, | 7 | 3 22 46 P.M. | — | — | — | — | — | — | ,, |
| 1,850 | ,, | 13 | 10 14 55 A.M. | — | — | — | — | — | — | ,, |
| 1,851 | ,, | 14 | 2 06 25 P.M. | — | — | — | — | — | — | ,, |
| 1,852 | ,, | 17 | 6 13 58 A.M. | — | — | — | — | — | — | ,, |
| 1,853 | ,, | 20 | 5 32 34 A.M. | — | — | — | — | — | — | ,, |
| 1,854 | ,, | 26 | 2 11 57 A.M. | — | — | — | — | — | — | ,, |
| 1,855 | ,, | 27 | 7 49 26 P.M. | — | — | — | — | — | — | ,, |
| 1,856 | ,, | 30 | 9 16 41 P.M. | — | — | — | — | — | — | ,, |
| 1,857 | IV. | 3 | 8 30 45 A.M. | — | — | — | — | — | — | ,, |
| 1,858 | ,, | 4 | 3 32 38 A.M. | — | — | — | — | — | — | ,, |
| 1,859 | ,, | 13 | 3 47 52 A.M. | — | — | — | — | — | — | ,, |
| 1,860 | ,, | 16 | 0 13 37 A.M. | — | — | — | — | — | — | ,, |
| 1,861 | ,, | 16 | 3 42 08 A.M. | — | — | — | — | — | — | ,, |
| 1,862 | ,, | 24 | 9 48 49 P.M. | — | — | — | — | — | — | ,, |
| 1,863 | ,, | 27 | 10 31 54 P.M. | — | — | — | — | — | — | ,, |
| 1,864 | ,, | 30 | 4 03 06 P.M. | — | — | — | — | — | — | ,, |
| 1,865 | V. | 3 | 4 42 59 A.M. | — | — | — | — | — | — | ,, |
| 1,866 | ,, | 3 | 6 29 39 A.M. | — | — | — | — | — | — | ,, |
| 1,867 | ,, | 4 | 11 36 47 P.M. | — | — | — | — | — | — | ,, |
| 1,868 | ,, | 5 | 8 57 21 P.M. | — | — | — | — | — | — | ,, |
| 1,869 | ,, | 6 | 6 46 35 A.M. | — | — | — | — | — | — | ,, |
| 1,870 | ,, | 6 | 7 34 0 A.M. | — | — | — | — | — | — | ,, |
| 1,871 | ,, | 6 | 9 40 51 A.M. | — | — | — | — | — | — | ,, |
| 1,872 | ,, | 6 | 7 53 43 P.M. | — | — | — | — | — | — | ,, |
| 1,873 | ,, | 7 | 2 59 15 A.M. | — | — | — | — | — | — | ,, |
| 1,874 | ,, | 9 | 11 01 09 A.M. | — | — | — | — | — | — | ,, |

CATALOGUE OF EARTHQUAKES—*continued.*

| No. | Month | Day | Time | Duration | Direction | Maximum Period and Amplitude of Horizontal Motion | | Maximum Period and Amplitude of Vertical Motion | | Nature of Shock |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | secs. | mm. | secs. | mm. | |
| | | | H. M. S. | M. S. | | | | | | |
| 1,875 | V. | 12 | 3 30 11 A.M. | — | — | — | — | — | — | slight |
| 1,876 | " | 12 | 6 19 36 P.M. | — | — | — | — | — | — | " |
| 1,877 | " | 13 | 2 28 59 P.M. | — | — | — | — | — | — | quick |
| 1,878 | " | 18 | 10 09 49 A.M. | — | — | — | — | — | — | slight |
| 1,879 | " | 19 | 6 25 13 A.M. | — | — | — | — | — | — | " |
| 1,880 | " | 23 | 9 23 0 P.M. | 3 40 | N.W., S.E. | 1·7 | 1·7 | — | — | slow |
| 1,881 | " | 27 | 10 25 32 A.M. | — | — | — | — | — | — | slight |
| 1,882 | VI. | 11 | 9 59 31 A.M. | — | — | — | — | — | — | " |
| 1,883 | " | 13 | 11 24 14 A.M. | — | — | — | — | — | — | " |
| 1,884 | " | 18 | 1 23 40 P.M. | — | — | — | — | — | — | " |
| 1,885 | " | 19 | 2 03 43 A.M. | — | — | — | — | — | — | " |
| 1,886 | " | 22 | 1 22 18 P.M. | — | — | — | — | — | — | " |
| 1,887 | " | 27 | 5 48 23 A.M. | 1 12 | S.E., N.W. | slight | | slight | | quick |
| 1,888 | VII. | 8 | 11 33 44 P.M. | — | — | — | — | — | — | slight |
| 1,889 | " | 21 | 10 12 52 P.M. | — | — | — | — | — | — | " |
| 1,890 | " | 22 | 9 54 53 A.M. | — | — | — | — | — | — | " |
| 1,891 | " | 22 | 6 31 44 P.M. | 4 34 | W.S.W., E.N.E. | 1·3 | 7·3 | 0·2 | 0·3 | slow, weak |
| 1,892 | " | 22 | 6 50 57 P.M. | — | — | — | — | — | — | slight |
| 1,893 | " | 28 | 3 30 50 P.M. | — | — | — | — | — | — | " |
| 1,894 | " | 29 | 6 34 59 A.M. | — | — | — | — | — | — | " |
| 1,895 | " | 29 | 6 57 46 A.M. | — | — | — | — | — | — | " |
| 1,896 | " | 29 | 10 31 54 A.M. | — | — | — | — | — | — | " |
| 1,897 | " | 29 | 10 44 50 P.M. | 1 50 | N.N.W., S.S.E. | 0·7 | 0·7 | slight | | " |
| 1,898 | " | 31 | 6 51 30 A.M. | — | — | — | — | — | — | " |
| 1,899 | VIII. | 2 | 2 02 47 A.M. | — | — | — | — | — | — | " |
| 1,900 | " | 4 | 10 19 22 P.M. | — | — | — | — | — | — | " |
| 1,901 | " | 5 | 9 12 23 A.M. | abt. 7 0 | — | — | — | — | — | slow, weak |
| 1,902 | " | 5 | 9 29 22 A.M. | — | — | — | — | — | — | slight |
| 1,903 | " | 5 | 9 45 51 A.M. | — | — | — | — | — | — | " |
| 1,904 | " | 5 | 10 21 09 A.M. | — | — | — | — | — | — | " |
| 1,905 | " | 5 | 10 44 23 A.M. | — | — | — | — | — | — | " |
| 1,906 | " | 5 | 11 31 04 A.M. | — | — | — | — | — | — | " |
| 1,907 | " | 5 | 4 20 40 P.M. | — | — | — | — | — | — | " |
| 1,908 | " | 5 | 6 54 42 P.M. | — | — | — | — | — | — | " |
| 1,909 | " | 6 | 3 59 30 A.M. | — | — | — | — | — | — | " |
| 1,910 | " | 6 | 4 15 39 A.M. | — | — | — | — | — | — | " |
| 1,911 | " | 6 | 8 48 57 A.M. | — | — | — | — | — | — | " |
| 1,912 | " | 8 | 4 37 09 A.M. | — | — | — | — | — | — | " |
| 1,913 | " | 8 | 11 55 36 A.M. | — | — | — | — | — | — | " |
| 1,914 | " | 8 | 6 28 46 A.M. | — | — | — | — | — | — | " |
| 1,915 | " | 12 | 10 51 04 A.M. | — | — | — | — | — | — | " |
| 1,916 | " | 16 | 11 48 01 A.M. | — | — | — | — | — | — | " |
| 1,917 | " | 16 | 4 53 33 P.M. | 3 0 | N.N.W., E.S.E. | 1·0 | 3 | — | — | slow, weak |
| 1,918 | " | 16 | 5 36 25 P.M. | — | — | — | — | — | — | slight |
| 1,919 | " | 16 | 6 11 35 P.M. | — | — | — | — | — | — | " |
| 1,920 | " | 18 | 11 55 27 A.M. | — | — | — | — | — | — | " |
| 1,921 | " | 21 | 0 28 16 A.M. | — | — | — | — | — | — | " |
| 1,922 | " | 21 | 6 29 28 A.M. | — | — | — | — | — | — | " |
| 1,923 | " | 22 | 0 23 58 A.M. | — | — | — | — | — | — | " |
| 1,924 | " | 25 | 5 14 33 A.M. | — | — | — | — | — | — | " |
| 1,925 | " | 27 | 1 03 46 A.M. | — | — | — | — | — | — | " |
| 1,926 | " | 27 | 6 19 20 A.M. | — | — | — | — | — | — | " |
| 1,927 | " | 27 | 8 46 19 A.M. | — | — | — | — | — | — | " |
| 1,928 | " | 28 | 4 02 0 P.M. | — | — | — | — | — | — | " |
| 1,929 | IX. | 8 | 11 44 36 A.M. | 1 15 | N.N.E., S.S.W. | 0·8 | 0·6 | slight | | quick, weak |
| 1,930 | " | 11 | 1 40 13 P.M. | — | — | — | — | — | — | slight |
| 1,931 | " | 21 | 9 02 12 A.M. | — | — | — | — | — | — | " |
| 1,932 | " | 23 | 6 27 03 A.M. | — | — | — | — | — | — | " |
| 1,933 | " | 26 | 9 59 18 P.M. | — | — | — | — | — | — | " |
| 1,934 | X. | 2 | 9 45 19 P.M. | 3 25 | W.S.W., E.N.E. | 1 | 1·8 | 0·4 | 0·2 | quick, weak |
| 1,935 | " | 7 | 1 40 02 P.M. | — | — | — | — | — | — | slight |
| 1,936 | " | 13 | 5 16 57 P.M. | — | — | — | — | — | — | " |
| 1,937 | " | 15 | 10 57 47 P.M. | — | — | — | — | — | — | " |
| 1,938 | " | 17 | 7 54 05 P.M. | — | — | — | — | — | — | " |
| 1,939 | " | 20 | 3 01 18 P.M. | 2 0 | S.E., N.W. | 0·3 | 1·0 | 0·2 | 0·3 | weak, quick |
| 1,940 | " | 25 | 10 11 10 A.M. | 0 50 | N.N.W., S.S.E. | 0·2 | 0·5 | — | — | quick |
| 1,941 | " | 26 | 10 18 39 P.M. | — | — | — | — | — | — | slight |
| 1,942 | XI. | 2 | 1 42 26 A.M. | — | — | — | — | — | — | " |

CATALOGUE OF EARTHQUAKES—*continued.*

| No. | Month | Day | Time | Duration | Direction | Maximum Period and Amplitude of Horizontal Motion. | | Maximum Period and Amplitude of Vertical Motion | | Nature of Shock |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | secs. | mm. | secs. | mm. | |
| | | | H. M. S. | M. S. | | | | | | |
| 1,943 | XI. | 5 | 6 44 11 A.M. | — | — | — | — | — | — | slight |
| 1,944 | „ | 9 | 9 39 28 A.M. | — | — | — | — | — | — | „ |
| 1,945 | „ | 11 | 5 29 53 A.M. | — | — | — | — | — | — | „ |
| 1,946 | „ | 13 | 3 06 36 A.M. | — | — | — | — | — | — | „ |
| 1,947 | „ | 13 | 6 16 24 A.M. | — | — | — | — | — | — | „ |
| 1,948 | „ | 14 | 9 13 43 A.M. | — | — | — | — | — | — | „ |
| 1,949 | „ | 15 | 6 06 39 A.M. | — | — | — | — | — | — | „ |
| 1,950 | „ | 16 | 8 03 16 A.M. | — | — | — | — | — | — | „ |
| 1,951 | „ | 19 | 10 16 22 A.M. | — | — | — | — | — | — | „ |
| 1,952 | „ | 20 | 3 05 01 A.M. | — | — | — | — | — | — | „ |
| 1,953 | „ | 22 | 10 04 36 A.M. | — | — | — | — | — | — | „ |
| 1,954 | „ | 23 | 5 56 54 P.M. | — | — | — | — | — | — | „ |
| 1,955 | „ | 24 | 9 06 54 A.M. | — | — | — | — | — | — | „ |
| 1,956 | „ | 27 | 0 12 56 A.M. | — | — | — | — | — | — | „ |
| 1,957 | XII. | 2 | 11 23 15 P.M. | — | — | — | — | — | — | „ |
| 1,958 | „ | 3 | 9 24 0 A.M. | — | — | — | — | — | — | „ |
| 1,959 | „ | 4 | 9 18 10 A.M. | 1 14 | S.S.W., N.N.E. | 0·8 | 0·5 | — | — | quick |
| 1,960 | „ | 5 | 8 08 21 A.M. | — | — | — | — | — | — | slight |
| 1,961 | „ | 6 | 2 03 45 A.M. | — | — | — | — | — | — | „ |
| 1,962 | „ | 7 | 5 25 31 P.M. | — | — | — | — | — | — | „ |
| 1,963 | „ | 8 | 5 23 11 P.M. | — | — | — | — | — | — | „ |
| 1,964 | „ | 10 | 8 04 42 P.M. | — | — | — | — | — | — | „ |
| 1,965 | „ | 12 | 6 40 49 A.M. | — | — | — | — | — | — | „ |
| 1,966 | „ | 13 | 10 57 57 P.M. | — | — | — | — | — | — | „ |
| 1,967 | „ | 16 | 8 47 43 P.M. | — | — | — | — | — | — | „ |
| 1,968 | „ | 17 | 9 26 19 P.M. | — | — | — | — | — | — | „ |
| 1,969 | „ | 19 | 3 16 26 A.M. | — | — | — | — | — | — | „ |
| 1,970 | „ | 19 | 1 21 26 P.M. | — | — | — | — | — | — | „ |
| 1,971 | „ | 21 | 5 14 41 A.M. | — | — | — | — | — | — | „ |
| 1,972 | „ | 23 | 3 36 11 A.M. | — | — | — | — | — | — | „ |
| 1,973 | „ | 23 | 8 45 53 A.M. | — | — | — | — | — | — | „ |
| 1,974 | „ | 23 | 0 26 04 P.M. | — | — | — | — | — | — | „ |
| 1,975 | „ | 23 | 11 03 27 P.M. | — | — | — | — | — | — | „ |
| 1,976 | „ | 24 | 3 36 26 P.M. | — | — | — | — | — | — | „ |
| 1,977 | „ | 26 | 4 41 25 P.M. | 3 20 | S.E., N.W. | 1·2 | 1·4 | — | — | weak, slow |
| 1,978 | „ | 31 | 11 52 14 P.M. | — | — | — | — | — | — | slight |
| | | | | | **1898.** | | | | | |
| 1,979 | I. | 5 | 5 21 01 P.M. | — | — | — | — | — | — | „ |
| 1,980 | „ | 13 | 8 16 22 A.M. | — | — | — | — | — | — | „ |
| 1,981 | „ | 14 | 2 30 06 A.M. | — | — | — | — | — | — | „ |
| 1,982 | „ | 27 | 10 43 27 P.M. | — | — | — | — | — | — | „ |

## IV.—EARTHQUAKES RECORDED AT SHIDE, AND ALSO AT OTHER STATIONS.

*Earthquakes recorded with a Milne Horizontal Pendulum at Shide, Isle of Wight,* 1897–98. *The time used is Greenwich mean (civil) time. Midnight* = 24 *or* 0 *hours. P.T.s = preliminary tremors. Duration means the interval of time over which movements continued.*

An asterisk (*) indicates Earthquakes which are discussed separately, or of which seismograms are reproduced.

| No. | Date | Time of Commencement | Remarks |
|---|---|---|---|
| | | **1897.** | |
| | | H. M. S. | |
| 96* | Mar. 23 | 16 19 12 | Small. |
| 97* | May 5 | 22 44 20 | „ |
| 98* | „ 9 | 23 50 38 | Large. Exact commencement lost. P.T.s at least 3m. Duration 47m. |

EARTHQUAKES RECORDED AT SHIDE, ETC.—*continued.*

| No. | Date | | Time of Commencement | Remarks. |
|---|---|---|---|---|
| 99* | May | 13 | 12 16 24 | Moderate. P.T.s 6m. Duration 36m. |
| 100* | „ | 23 | 13 15 20 | Small. |
| 101* | „ | 24 | 0 18 59 | Moderate. |
| 102* | „ | 24 | 1 48 19 | Small. |
| 103* | „ | 24 | 4 30 59 | „ |
| 104* | June | 3 | 9 57 18 | Large. P.T.s 17m. Duration 2h. |
| 105* | „ | 12 | 11 29 10 | Large. Exact commencement lost. Period of large waves 15s. Range 10mm. Origin, Assam. P.T.s exceed 10m. |
| 106* | „ | 12 | 19 53 19 | Small. Duration 10m. |
| 107* | „ | 13 | 7 39 33 | „ „ 7m. |
| 108* | „ | 13 | 10 51 33 | „ „ 10m. Three maxima. |
| 109 | „ | 20 | 20 58 40 | „ „ 16m. |
| 110 | „ | 21 | 20 14 43 | „ „ 8m. |
| 111 | „ | 22 | 14 11 40 | „ „ 8m. |
| 112* | „ | 24 | 19 34 53 | Ends 20h. 43m. 15s. Large. Origin, Albania. |
| 113* | „ | 30 | 4 39 33 | Small. |
| 114* | „ | 30 | 15 0 2 | Slight. Origin, Epirus. |
| 115* | July | 17 | 7 57 9 | Small. |
| 116* | „ | 21 | 13 33 32 | Very large. P.T.s 7m. Two large maxima. |
| 117* | „ | 22 | 11 20 0 | Moderate. Commencement lost. |
| 118* | Aug. | 2 | 15 46 39 | Small. |
| 119* | „ | 5 | 0 22 35 | Very large. P.T.s 30m. Duration over 3h. Origin, Japan. |
| 120* | „ | 16 | 8 6 29 | Slight. Ends 8h. 56m. 22s. |
| 121 | „ | 17 | 6 41 17 | Small. |
| 122* | „ | 26 | 17 1 41 | „ |
| 123* | „ | 26 | 21 40 30 | „ |
| 124* | „ | 26 | 22 13 14 | Moderate. P.T.s 2m. 44s. |
| 125 | „ | 29 | 6 16 17 | „ „ 4m. |
| 126 | „ | 31 | 15 4 19 | Small. |
| 127 | Sept. | 1 | 18 29 41 | „ |
| 128 | „ | 5 | 1 21 59 | „ |
| 129 | „ | 5 | 1 36 50 | „ |
| 130 | „ | 12 | 22 54 18 | „ |
| 131* | „ | 17 | 15 59 58 | Large. P.T.s 8m. Duration 40m. |
| 132* | „ | 17 | 17 59 58 | „ „ 8m. „ 38m. |
| 133* | „ | 20 | 19 24 47 | „ „ 40m. „ 2h. 56m. Origin, E. of Borneo. |
| 134* | „ | 21 | 5 28 51 | Large. P.T.s 43m. Duration 2h. 56m. Origin, E. of Borneo. |
| 135* | „ | 21 | 11 36 44 | Slight. Ends 13h. 20m. 20s. |
| 136 | „ | 24 | 23 58 56 | Small. |
| 137 | „ | 25 | 18 3 39 | „ |
| 138* | Oct. | 2 | 13 36 39 | Moderate. Duration 27m. |
| 139* | „ | 3 | 15 7 9 | Small. |
| 140* | „ | 19 | 0 6 52 | Large. P.T.s 41m. Duration 2h. 30m. |
| 141* | „ | 20 | 14 43 29 | „ „ 42m. „ 2h. 33m. |
| 142* | „ | 23 | 3 19 0 | Slight. Ends 3h. 28m. 29s. |
| 143 | „ | 23 | 17 49 56 | Small. |
| 144 | „ | 31 | 2 0 0 | About this time. Small. |
| 145 | „ | 31 | 17 0 0 | „ „ „ Large. |
| 146* | Nov. | 14 | 14 53 35 | Small. Duration 22m. |
| 147 | „ | 17 | 3 28 47 | „ |
| 148 | „ | 20 | 17 33 21 | „ |
| 149 | „ | 22 | 8 or 9 48 45 | „ |
| 150 | „ | 23 | 4 56 44 | „ |
| 151 | „ | 23 | 9 34 22 | „ |

EARTHQUAKES RECORDED AT SHIDE, ETC.—*continued.*

| No. | Date | Time of Commencement | Remarks |
|---|---|---|---|
| 152* | Nov. 25 | 10 1 48 | Large. Ends 12h. |
| 153* | Dec. 11 | 10 4 31 | Small. Duration 45m. |
| 154 | ,, 17 | 10 20 58 | Moderate. |
| 155* | ,, 17 | 18 30 0 | Slight. Ends 10m. 30s. on 18th. |
| 156* | ,, 28 | 20 54 21 | Moderate. P.T.s 8m. Duration 24m. Observed in Toronto at 20h. 24m. 37s. |
| 157* | ,, 29 | 11 40 48 | Large. P.T.s 19m. Duration 1h. 22m. 28s. Origin, N. of Hayti. Observed in Toronto 11h. 32m. 29s. |
| 158* | — | — | Dec. 29 to Jan. 1, slight tremors. |
| | | **1898.** | |
| 159 | Jan. 3 | 14 41 2 | Small. |
| 160 | ,, 3 | 15 7 15 | ,, |
| 161* | ,, 24 | 23 45 49 | Large. P.T.s 16m. Duration 33m. On smoked paper, NS component, 8m. 34s. Toronto, 13m. 30s. on the 25th. |
| 162* | ,, 29 | 13 44 8 | Small. P.T.s 5m. 47s. Duration 13m. 1s. |
| 163* | ,, 29 | 15 5 25 | Large. P.T.s 9m. 30s. Duration 1h. 1m. Smoked paper, NS component, 15h. 5m. 26s. |
| 164* | Feb. 5 | 8 36 13 | End 9h. 19m. 28s. Record on smoked paper. |
| 165 | ,, 7 | 23 35 20 | Small. |
| 166 | ,, 8 | 1 47 32 | ,, |
| 167 | ,, 8 | 23 5 47 | ,, |
| 168 | ,, 9 | 22 57 36 | ,, Duration 15m. |
| 169 | ,, 16 | 17 9 8 | ,, and three others within 54m. |

NOTE.—On February 5, about 9 A.M., when there were slight disturbances in Catania, Catanzaro (Calabria), Rome, and Livorno, and February 18, between 16h. 30m. and 17h. 30m., when there were feeble movements recorded at Catania, Ischia, Rocca di Papa, and Rome. The clock driving the photographic film at Shide had stopped. On the 5th it will be observed that a record was obtained on smoked paper.

*Note on the Edinburgh Bifilar. Extracted from a Letter received from* Mr. THOMAS HEATH, *of the Royal Observatory, Edinburgh.*

An inspection of the photograph shows but little trace of the diurnal wave. Measurements of the change of position of the light spot for every four hours throughout the month of March 1898 results in an irregular curve, which apparently indicates a slight movement to the north from noon to midnight, and to the south from midnight to noon. Maximum and minimum thermometers are being established in the bifilar room.

The mean of daily measurements between February 28 and April 2 indicate that the new movement of the light spot corresponds to a tilt of $1''\cdot74$ of the frame. The photographs have not been subjected to the examination necessary to show whether there is a lunar effect.

The instrument was first mounted in March 1894, at Carlton Hill, and removed to its present site, on Blackford Hill, in October 1895. It was mounted with photo-recording apparatus in August 1896. A second pendulum purchased out of grant from the Scientific Research Committee of the Royal Society was mounted in May 1898.

*Movements recorded by a Darwin Bifilar Pendulum at the Royal Observatory, Edinburgh. Director,* Dr. R. COPELAND.

The instrument was presented to the Observatory by the late M. ANTOINE D'ABBADIE in 1894.

| No. | Shide No. | Date | | Time, G.M.T. | Remarks |
|---|---|---|---|---|---|
| | | | | H. M. S. | |
| 1 | 104 | June | 3 | 10 57 0 | Slight oscillations and widening of line. |
| 2 | 105 | ,, | 12 | 11 18 0 | Ends at 13h. 12m. |
| 3 | 116 | ,, | 21 | 13 40 0 | Fine oscillatory disturbance until 14h. 4m. |
| 4 | 119 | Aug. | 5 | 1 2 30 | Fine oscillatory disturbance until 1h. 40m. 30s. |
| 5 | 131 | Sept. | 17 | 15 55 0 | Small oscillatory disturbance until 16h. 5m. |
| 6 | 132 | ,, | 17 | 18 2 0 | Small oscillatory disturbance until 18h. 12m. |
| 7 | 133 | ,, | 20 | 19 56 0 | Small oscillatory disturbance until 20h. 28m. Smaller oscillations 20h. 17m. to 20h. 28m. |
| 8 | 134 | ,, | 21 | 6 7 30 | Like preceding until 6h. 38m. 30s. |
| 9 | 139 | Oct. | 3 | 14 58 0 | Very slight tilt to N. |
| 10 | 140 | ,, | 19 | 0 28 0 | Small oscillatory disturbance until 50m. |
| 11 | 141 | ,, | 20 | 15 20 0 | Small oscillatory disturbance until 15h. 33m. |
| 12 | 146 | Nov. | 14 | 15 29 0 | Tilt to N. |
| 13 | 163 | Jan. | 29 | 15 15 0 | Small oscillatory disturbance until 15h. 25m. |

*Observations at Rocca di Papa. By Dr. A. Cancani.*

*Instruments described on pp. 264–266.*

| No. | Shide No. | Date | | Commencement | Maximum | Remarks |
|---|---|---|---|---|---|---|
| | | 1897 | | H. M. S. | H. M. S. | |
| 1 | 100 | May | 23 | — | 13 17 10 | Small undulation. |
| 2 | 104 | June | 3 | 9 54 30 | 10 34 0 | End at 10h. 40m. Period 24s. |
| 3 | 105 | ,, | 12 | 11 18 0 | 11 47 10 | At 11h. 36m. Period 16s. |
| 4 | 116 | July | 21 | — | 13 50 0 | At 13h. 45m. Period 10s. |
| 5 | 117 | ,, | 22 | — | 11 26 0 | — |
| 6 | 119 | Aug. | 5 | 0 32 40 | 1 8 30 | End 2h. 12m. |
| 7 | 122 | ,, | 26 | 16 46 30 | 17 0 0 | Period 18s. |
| 8 | 124 | ,, | 26 | 22 8 30 | 22 15 30 | End 22h. 30m. |
| 9 | 131 | Sept. | 17 | 15 50 0 | 15 55 0 | Period 18s. |
| 10 | 132 | ,, | 17 | 17 48 0 | 18 6 0 | — |
| 11 | 133 | ,, | 20 | 19 25 0 | 19 40 0 | Period 18s. End 21h. 5m. |
| 12 | 134 | ,, | 21 | 5 32 8 | 5 46 0 | End 7h. |
| 13 | 140 | Oct. | 19 | 0 5 30 | 0 51 0 | Period 32s. At 25m. End 1h. 15m. |
| 14 | 141 | ,, | 20 | 15 0 0 | 15 30 0 | End 17h. Period 16s. |
| 15 | 157 | Dec. | 29 | 11 56 0 | 12 5 30 | End 12h. 23m. E.W. component large. N.S. small. |
| | | 1898 | | | | |
| 16 | 161 | Jan. | 24 | 23 49 0 | 0 15 15 | End 45m., January 25 |
| 17 | 162 | ,, | 29 | 13 39 0 | 13 39 17 | End 13h. 45m. E.W. component. |
| — | — | — | | 13 40 0 | — | End 13h. 40m. 30s N.S. component small. |
| 18 | 163 | Jan. | 29 | 15 5 15 | 15 11 0 | Max. in P.Ts. 15h. 9m. 50s. Waves commence 15h. 10m. 45s. |
| — | — | — | | — | 15 11 45 | End 15h. 40m. for E.W. |
| — | — | — | | — | 15 13 30 | N.S. component not so distinct. |

*Records from W. E. Plummer, Esq., Liverpool Observatory, Bidstone, Birkenhead. Instrument a Darwin Bifilar Pendulum, provided by the British Association.*

| No. | Shide No. | Date | Time | Remarks |
|---|---|---|---|---|
| | | | **1897.** | |
| | | | H. M. H. M. | |
| 1 | — | Sept. 6 | 12 20 to 12 25 | Small. |
| 2 | 132 | ,, 17 | 18 10 ,, 18 19 | Very small. |
| 3 | — | ,, 19 | 7 22 ,, 7 30 | Small. September 20 to 22 records not taken. |
| 4 | — | ,, 23 | 12 4 ,, 12 20 | Motion 0″·008. |
| 5 | — | ,, 24 | 15 3 | Small. September 28 to October 1 records not taken. |
| 6 | 139 | Oct. 3 | 16 50 ,, 16 55 | Small. October 24 to 26, records imperfect. |
| 7 | — | ,, 27 | 17 55 ,, 18 30 | Slight disturbance. October 29 to November 21 instrument dismounted. |
| 8 | — | Nov. 24 | 11 21 ,, 11 31 | Displacement 0″·12. |
| 9 | — | ,, 26 | 15 30 ,, 16 40 | Slight and irregular. |
| 10 | — | ,, 27 | 14 0 ,, 19 0 | ,, ,, ,, |
| 11 | — | Dec. 5 | 14 30 ,, 15 10 | Slight. |
| 12 | 153 | ,, 11 | 9 50 ,, 11 10 | ,, |
| 13 | — | ,, 14 | 10 30 ,, 14 30 | Displacement 0″·1. |
| 14 | 157? | ,, 29 | 8 30 ,, 9 0 | Slight disturbance. |
| | | | **1898.** | |
| 15 | — | Jan. 7 | 2 0 ,, 2 10 | Very slight. January 20 to 22 clock stopped. |
| 16 | — | ,, 24 | 14 0 | Uncertain and very slight. |
| 17 | — | Feb. 2 | 9 50 ,, 11 30 | Moderate. |
| 18 | — | ,, 6 | 18 4 ,, 18 10 | Slight. |
| 19 | — | ,, 7 | 13 0 ,, 15 0 | ,, movement. |
| 20 | 169 | ,, 16 | 17 30 | ,, ,, |
| 21 | — | ,, 18 | 15 25 ,, 16 30 | ,, ,, |
| 22 | — | ,, 20 | 3 0 ,, 8 0 | Most considerable disturbance. Motion 0″·17. |
| 23 | — | ,, 20 | 18 30 | Disturbance. |
| 24 | — | ,, 24 | 14 22 ,, 14 40 | Slight. |
| 25 | — | Mar. 2 | 0 11 ,, 0 30 | Moderate. On 15th no record. |
| 26 | — | ,, 7 | 14 0 ,, 18 0 | Trace irregular. |
| 27 | — | ,, 8 | 4 0 ,, 8 0 | ,, ,, |
| 28 | — | ,, 11 | 17 0 About | Slight. |
| 29 | — | ,, 12 | 2 0 ,, 4 0 | Slight |
| 30 | — | ,, 24 | 8 20 ,, 15 0 | Trace irregular. |
| 31 | — | ,, 27 | 5 0 ,, Noon | ,, ,, |
| 32 | — | ,, 27 | 20 50 ,, 21 23 | Slight. |
| 33 | —? | ,, 28 | 12 0 ,, 12 40 | Moderate. |

*Records received from Professor Kortazzi, Nicolaiew. The recording instrument was a von Rebeur-Paschwitz Horizontal Pendulum. Max = maximum. Dur = duration.*

| No. | Shide No. | Date | | Commencement G.M.T. | | | Remarks |
|---|---|---|---|---|---|---|---|
| | | 1897 | | H. | M. | S. | |
| 1 | 97 | May | 5 | 22 | 12 | 0 | Max. 22h. 27m. Dur. 1h. |
| 2 | 99 | ,, | 13 | 12 | 2 | 0 | Very large. P.T.s 18m. Dur. 2h. 8m. |
| 3 | 100 | ,, | 23 | 12 | 48 | 0 | Moderate. Max. 13h. 9m. Dur. 59m. |
| 4 | 101 | ,, | 24 | 23 | 57 | 0 | Large. P.T.s 9m. Max. 20m. Dur. 1h. 4m. |
| | | | | | | | No observations from June 3 to 29. |
| 5 | 113 | June | 30 | 3 | 50 | 0 | Moderate. Max. 4h. 16m. Dur. 44m. |
| 6 | 115 | July | 17 | 7 | 48 | 0 | Small. Max. 7h. 50m. 5s. Dur. 26m. |
| 7 | 116 | ,, | 21 | 13 | 43 | 0 | Large. Dur. 35m. P.T.s 4m. |
| 8 | 117 | ,, | 22 | 9 | 52 | 0 | ,, ,, 67m. ,, 11m. |
| 9 | 118 | Aug. | 2 | 15 | 29 | 0 | Small. ,, 10m. |
| 10 | 119 | ,, | 5 | 0 | 17 | 0 | Very large. Max. 31m. Dur. 3h. 35m. |
| 11 | 122 | ,, | 26 | 16 | 32 | 0 | Small. Max. 16h. 46m. Dur. 45m. |
| 12 | 123 | ,, | 26 | 21 | 40 | 0 | ,, ,, 21h. 57m. ,, 42m. |
| 13 | 131 | Sept. | 17 | 15 | 40 | 0 | Very large. Max. 15h. 45m. Dur. 44m. Origin, Tashkent. |
| 14 | 132 | ,, | 17 | 18 | 0 | 0 | Small. Details lost. |
| 15 | 133 | ,, | 20 | 19 | 23 | 30 | Very large. Max. 19h. 29m. 5s. Dur. 4h. |
| 16 | 134 | ,, | 21 | 4 | 57 | 0 | Very large. Max. 5h. 7m. The end lost. |
| 17 | 138 | Oct. | 2 | 12 | 56 | 30 | ,, ,, Max. 13h. 30m. Dur. 1h. 36m. |
| 18 | 140 | ,, | 19 | 0 | 13 | 0 | Very large. Max. 42m. Dur. 3h. 1m. P.T.s 7m. |
| 19 | 141 | ,, | 20 | 14 | 49 | 0 | Very large. Max. 15h. 37m. Dur. 3h. 4m. P.T.s 11m. |
| 20 | 153 | Dec. | 11 | 10 | 9 | 0 | Moderate. Max. 10h. 28m. Dur. 1h. 10m. |
| 21 | 156 | ,, | 28 | 20 | 53 | 0 | Small. Max. 21h. 4m. 30s. Dur. 29m. |
| 22 | 157 | ,, | 29 | 11 | 47 | 0 | Small. Max. 11h. 55m. and 12h. 7m. Dur. 2h. 5m. |
| | | 1898 | | | | | |
| 23 | 161 | Jan. | 24 | 23 | 49 | 30 | Very large. Max. 5m. Dur. 37m. 5s. |
| 24 | 162 | ,, | 29 | 13 | 33 | 0 | Small. Dur. 19m. |
| 25 | 163 | ,, | 29 | 15 | 4 | 0 | Very large. Max. 15h. 10m. Dur. 58m. |

*Earthquakes recorded at Shide and also at Distant Localities.*

For a collective statement regarding earthquakes recorded in Italy I am indebted to Professor P. Tacchini, Director of the R. Ufficio Centrale di Meteorologia e di Geodinamica al Collegio Romano, Via del Caravita N° 7, Roma. He writes me that records from Padua have not been received since August 1897.

Professor Stupart's records from the Meteorological Observatory, Toronto, date from December 28, 1897.

| The Shide Numbers | Rome | Rocca di Papa | Padua | Sienne | Pavia | Ischia | Italy generally | Catania | Toronto | Edinburgh | Bidstone | Nicolaiew |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 97 | | | | | | | | | | | | — |
| 99 | | | | | | | | | | | | — |
| 100 | | — | — | | | — | | — | | | | — |
| 101 | — | — | — | — | — | — | | — | | | | — |
| 102 | — | | | | | — | | | | | | |
| 104 | — | — | — | — | | — | | — | | — | | |
| 105 | | | | | | | — | | | — | | |
| 112 | — | | — | | | — | | | | | | |
| 113 | | | | | | | | | | | | — |
| 114 | | | | | | | — | | | | | |
| 115 | | | | | | | | | | | | — |
| 116 | | | | | | | — | | | — | | — |
| 117 | | — | | | | — | | — | | | | — |
| 118 | | | | | | | | | | | | — |
| 119 | | | | | | | — | | | — | | — |
| 120 | — | — | — | | | — | | — | | | | |
| 122 | — | — | | | | — | | | | | | — |
| 123 | — | — | | | | — | | | | | | — |
| 124 | — | — | | | | — | | | | | | |
| 131 | — | — | | | | — | | — | | — | | — |
| 132 | — | — | | | | — | | — | | — | — | — |
| 133 | — | — | | | | — | | — | | — | | — |
| 134 | — | — | | | | — | | — | | — | | — |
| 135 | | | | | | | — | | | | | |
| 138 | — | | | | | | | — | | | | — |
| 139 | | | | | | | | | | — | — | |
| 140 | — | — | | | | — | | — | | — | | — |
| 141 | — | — | | | | — | | — | | — | | — |
| 142 | — | | | | | — | | — | | | | |
| 146 | | | | | | | | | | — | | |
| 152 | | | | | | | | — | | | | |
| 153 | | | | | | | | — | | | — | — |
| 156 | | | | | | | | | — | | | — |
| 157 | | | | | | | — | | — | | — | — |
| 161 | | | | | | | — | | — | | | — |
| 162 | | | | | | | — | | | | | — |
| 163 | | | | | | | — | | | — | | — |
| 164 | — | | | | | | | — | | | | |

*Observations at the R. Osservatorio di Catania e dell' Etna. By Dr. A. Riccò.* 1897–1898.

Instrument a long pendulum, p. 259.

| No. | Shide No. | Date | Commencement G.M.T. H. M. S. | Remarks |
|---|---|---|---|---|
| 1 | 100 | Mar. 23 | 13 20 6 | Small |
| 2 | 101 | „ 24 | 0 51 46 | Small. Also 1h. 0m. 2s. and 1h. 5m. 49s. |
| 3 | 104 | June 3 | 9 53 42 | „ Duration 1h. 35m. 37s. |
| 4 | 105 | „ 12 | 11 17 22 | Very large. Duration 4h. 51m. 38s. Max. range 32mm. Period of large waves 11s. |
| 5 | 116 | July 21 | 13 39 4 | Moderate. P.Ts. 1m. 23s. Duration 1h. 15m. 29s. |
| 6 | 117 | „ 22 | 9 4 53 | Small. Exact commencement lost |
| 7 | 118 | Aug. 2 | 15 0 17 | „ „ „ „ |
| 8 | 119 | „ 5 | 0 24 35 | Moderate. P.Ts. 10m. 29s. Duration 2h. 40m. 53s. |
| 9 | 131 | Sept. 17 | 15 15 50 | Small. Duration 2h. 36m. 47s. |
| 10 | 133 | „ 20 | 19 25 2 | „ Period of large waves 11·5s. Duration 2h. 10m. 45s. |
| 11 | 134 | „ 21 | 5 29 32 | Small |
| 12 | 138 | Oct. 2 | 13 31 51 | Small. Period of large waves 11s. Duration 32m. 11s. |
| 13 | 140 | „ 19 | 0 6 36 | Small. Period of large waves 12s. Duration 52m. 42s. |
| 14 | 141 | „ 20 | 14 49 26 | Small |
| 15 | 153 | Dec. 11 | 9 51 28 | Small. P.Ts. 14m. 21s. Duration 1h. 20m. 54s. |
| 16 | 157 | „ 29 | 11 29 10 | Small. Period of large waves 23s. Duration 1h. 30m. 50s. |
| 17 | 162 | Jan. 29 | 14 4 41 | Large. P.Ts. 1h. 2m. 19s. Range 18 mm. Duration 1h. 33m. 51s. |

## *Deductions based on the Preceding Records.*

In order to determine the areas over which each of the earthquakes recorded at Shide had been perceptible a list of these (see p. 191) was sent to observatories at the following places :—

Edinburgh,* Bidstone,* Strassburg, Padua, Rome,* Rocca di Papa,* Catania,* Ischia, Nicolaiew,* Charkow, Potsdam,* Toronto.*

Replies have been received from those stations marked with an asterisk. Dr. P. Tacchini, Director of the Ufficio Centrale di Meteorologia e di Geodinamica at Rome, in replying, called my attention to several earthquakes which had been well recorded in Italy, but which did not appear on my list. A re-examination of my seismograms led to the discovery of certain of these, and the numbers on the Shide list were increased from 160 to 169.

Records which ought to be strictly comparable are those from Shide, Toronto, and other stations at which the free horizontal pendulums adopted by this committee have been established.

The records from Strassburg, Nicolaiew, Potsdam, and from stations at which there are free horizontal pendulums of the von Rebeur-Paschwitz or Ehlert types, provided that these instruments have been adjusted with like degrees of sensibility, should also be comparable amongst themselves.

If, however, certain of these instruments have been so arranged that their stability is feeble, or, in other words, so that their free period is large as compared with that of others, they can hardly be expected, even when placed side by side, to yield similar seismograms. A small horizontal pendulum with a period of, say, 50 seconds and a large multiplication may be continuously in movement over a considerable period of time. This being the case, it may often happen that the exact commencement of an earthquake may not be determinable. In the Strassburg records, for example, we find commencements of movement given so many minutes in advance of other stations in Europe that for the present, at least, we are inclined to accept the conclusions to which they lead with some reserve (see Earthquake No. 83).

In Italy there is a great variety of instruments which, for the most part, record with ink upon the surface of paper, or by means of indices writing on smoked paper.

The ordinary pendulums vary in length from a few metres up to 25 metres in length. In Catania, for example, there is a pendulum 25 metres in length, carrying a bob of 300 kgs., and with writing indices multiplying its movements 12·5 times. It appears that these exceedingly long pendulums are sometimes affected by the action of the wind upon the building in which they are suspended. When this occurs it becomes difficult to determine with exactness the time at which an earthquake has its commencement.

The horizontal pendulums are also characterised by their great size. The horizontal booms of such instruments at Rocca di Papa, which carry 25 kgs. near their outer end, are 2·7 metres in length, the tie running to a point 5·25 metres above the foot of each boom. They write with ink on a band of paper moving at a rate of 60 cm., or 2 feet, per hour. The open diagrams obtained from both types of instrument are excellent (see p. 207). Unfortunately, the enormous dimensions of these instruments preclude any extensive adoption by private observers. When these dimensions are reduced, as, for example, with the ordinary pendulums, the smaller of these, not having sufficient multiplication or inertia to overcome the frictional resistance of writing indices, fail in a greater or lesser degree to record the small preliminary tremors, with the result that the time at which an earthquake commences is apparently retarded.

It is probably sometimes this which explains the great difference in the recorded times at which earthquakes originating at great distances have announced themselves at different recording stations in Italy and Europe.

For description of instruments in Italy and at Strassburg see pp. 258–272.

Since writing the Report for 1897 I have obtained a list of records from Japan and the catalogue issued from time to time by Professor Pietro Tacchini in the 'Bollettino della Società Sismologica Italiana.' Materials extracted from these sources enable me to throw further light upon records published in 1897.

*No.* 1, June 15, 1896. (B.A. Report, 1897.)

This is the disastrous shock the sea waves accompanying which occasioned the loss of nearly 30,000 lives on the N.E. coast of Japan, a description of which will be found in the Report for 1897.

*Velocity of Propagation of Earth-waves.*

| | H. | M. | S. | | M. | S. |
|---|---|---|---|---|---|---|
| Time at origin . . | 10 | 31 | 0 | | | |
| Padua . . . | 10 | 46 | 57 | Time to travel. . . | 15 | 57 |
| Ischia . . . | 10 | 50 | 29 | " " " . . | 19 | 29 |
| Rocca di Papa . | 10 | 56 | 18 | " " " . . . | 25 | 18 |
| Catania (about) . | 11 | 0 | 0 | " " " . . . | 29 | 0 |
| Rome . . . | 11 | 19 | 20 | " " " . . . | 48 | 20 |

| — | Distance on arc kms. | Distance on chord kms. | Velocity on arc km. per sec. | Velocity on chord km. per sec. |
|---|---|---|---|---|
| Padua . . . . . | 9490 | 8592 | 9·9 | 8·9 |
| Ischia . . . . . | 9879 | 8910 | 8·4 | 7·6 |
| Rocca di Papa . . . | 9879 | 8910 | 6·5 | 5·8 |
| Catania . . . . . | 9990 | 8993 | 5·7 | 5·1 |
| Rome . . . . . | 9879 | 8910 | 3·4 | 3·0 |

*Instruments employed.*

| | |
|---|---|
| Padua . . | Microseismograph (Vicentini) Pendulum, 1·5 m. Bob, 50 kgs. Free period, 2·4 secs. Multiplication by indices, 70 to 80. |
| Ischia . . | Horizontal Pendulum. Bob, 12 kgs. Free period, 11 secs. |
| Rocca di Papa. | Pendulum, 15 m. Bob, 200 kgs. |
| Catania . . | Pendulum, 25·3 m. Bob, 300 kgs. |
| Rome . . | Pendulum, 8 m. Bob, 100 kgs. |

*No.* 83, February 7, 1897. (B.A. Report, 1897).

| | H. | M. | S. | Pts. 26 min. 40 secs. Duration, 1 hr. 6 mins. |
|---|---|---|---|---|
| Strassburg . | 7 | 45 | 4 | Horizontal pendulum and photo record. |
| Edinburgh . | 7 | 49 | 7 | Bifilar pendulum and photo record. |
| Padua . . | 7 | 49 | 30 | Pendulum (Vicentini). |
| Ischia . . | 7 | 50 | 6 | Horizontal pendulum, 12 kgs. |
| Potsdam . . | 7 | 55 | 0 | Horizontal pendulum and photo record. |
| Nicolaiew . | 7 | 57 | 1 | " " " " |
| Shide . . | 7 | 59 | 3 | " " " " |
| Rocca di Papa . | 8 | 20 | 0 | Pendulum, 15 m., 250 kgs. |
| Catania . . | 8 | 22 | 43 | Pendulum, 25 m., 300 kgs. |
| Rome . . | 8 | 25 | 0 | Pendulum, 16 m., 200 kgs. |
| Tokio . . | 7 | 38 | 33 | Duration by seismograph, 5·47. Slow movement. |

At Ischia the period of the large waves reached 18·5 secs. The natural period of the pendulums in the meridian and at right angles was 12·9 secs. and 16·4 secs.

At Rocca di Papa there were also two horizontal pendulums carrying 30 kgs., and with periods of 20 secs. The N.S. component commenced at 8 hrs. 25 mins., and the E.W. component at 8 hrs. 23 mins. 40 secs.

At Catania the N.W.-S.E. component commenced at 8 hrs. 22 mins. 43 secs. ; N.E.-S.W. component commenced at 8 hrs. 27 mins. 49 secs.

*Velocity of Propagation.*—For reasons similar to those given for Earthquake No. 100, I shall assume that this disturbance had the same origin as No. 100, and that it occurred at least 2 mins. 30 secs. earlier than it was noted in Tokio. The time at which it originated is therefore 7 hrs. 36 mins. On this assumption the following table has been calculated :—

| — | Time to travel | Distance on arc in degrees and kms. | Distance on chord in kms. | Velocity on arc km. per sec. | Velocity on chord km. per sec. |
|---|---|---|---|---|---|
| | M. S. | ° | | | |
| Strassburg . | 9 4 | 85·2 = 9457 | 8592 | 17·0 | 15·0 |
| Edinburgh . | 13 7 | 85·0 = 9435 | 8592 | 12·0 | 10·9 |
| Padua . . | 13 30 | 85·5 = 9490 | 8592 | 11·7 | 10·6 |
| Ischia . . | 14 6 | 89·0 = 9879 | 8910 | 11·6 | 10·5 |
| Potsdam . . | 19 0 | 79·7 = 8846 | 8172 | 7·7 | 7·1 |
| Nicolaiew. . | 21 1 | 77·5 = 8658 | 8000 | 6·8 | 6·3 |
| Shide . . | 23 3 | 86·5 = 9601 | 8700 | 7·0 | 6·3 |
| Rocca di Papa . | 44 0 | 89·0 = 9879 | 8904 | 3·7 | 3·3 |
| Catania . . | 46 43 | 90·0 = 9990 | 8993 | 3·5 | 3·2 |
| Rome . . | 49 0 | 89·0 = 9879 | 8910 | 3·3 | 3·0 |

*No.* 84, February 7, 1897. (B.A. Report, 1897.)

| | H. | M. | S. | |
|---|---|---|---|---|
| Shide . . . . . . . . . . | 23 | 54 | 50 | (Corrected) |
| Potsdam . . . . . . . . . | 23 | 52 | 0 | |

*No.* 85, February 13, 1897. (B.A. Report, 1897.)

| | H. | M. | S. |
|---|---|---|---|
| Shide . . . . . . . . . . . . . | 2 | 8 | 11 |
| Potsdam . . . . . . . . . . . . | 2 | 5 | 0 |
| Rome . . . . . . . . . . . . . | 2 | 5 | 50 |
| Nicolaiew . . . . . . . . . . . . | 2 | 6 | 1 |
| Edinburgh . . . . . . . . . . . . | 2 | 3 | 12 |
| Strassburg . . . . . . . . . . . . | 2 | 31 | 54 |

Not recorded at Catania, Ischia, and Rocca di Papa.

*No.* 86, February 13, 1897. (B.A. Report, 1897.)

| | H. | M. | S. | | M. | S. |
|---|---|---|---|---|---|---|
| Shide . . . . . . . | 15 | 23 | 36 | Duration | 9 | 20 |
| Potsdam . . . . . . | 15 | 18 | 0 | | | |

*No.* 87, February 15, 1897. (B.A. Report, 1897.)

| | H. | M. | S. |
|---|---|---|---|
| Nicolaiew . . . . . . . . . . . . | 22 | 12 | 0 |
| Edinburgh . . . . . . . . . . . . | 22 | 17 | 0 |
| Potsdam . . . . . . . . . . . . | 22 | 20 | 0 |

At Shide on the night of the 15th–16th there were intermittent switchings of the boom.

February 19, 1897.

At Shide instrument not working.

| | H. | M. | S. | |
|---|---|---|---|---|
| Padua. . . . | 20 | 51 | 23 | |
| Verona . . . | 20 | 58 | 0 | Pendulum (Vicentini) |
| Rome . . . . | 20 | 59 | 50 | |
| Ischia . . . . | 21 | 1 | 25 | Period reached, 22·6 secs. |
| Catania . . . | 21 | 5 | 25 | N.E.–S.W. component. Period reached, 32 secs. |
| „ . . . | 21 | 6 | 42 | S.E.–N.W. |
| Rocca di Papa . | 21 | 11 | 0 | |

| | H. | M. | S. | |
|---|---|---|---|---|
| Pavia . . . | 21 | 42 | 12 | Pendulum, 4½ m. 40 kgs. |
| Nicolaiew . . | 20 | 52 | 1 | |
| Potsdam . . | 21 | 2 | 0 | (about) |
| Strassburg . . | 21 | 11 | 39 | S.W.–N.E. component |
| " . . | 22 | 25 | 0 | E.–W. |
| Edinburgh . . | 21 | 30 | 0 | |
| Japan . . . | 20 | 41 | 0 | Not recorded in Tokio |

*No.* 88, February 20, 1897. (B.A. Report, 1897.)

| | H. | M. | S. | | H. | M. | S. |
|---|---|---|---|---|---|---|---|
| Shide . . . . | 0 | 17 | 47 | Four separate maxima ending | 1 | 16 | 27 |
| Rocca di Papa . | 23 | 55 | 0 | On the 19th | | | |
| Verona . . . | 0 | 12 | 0 | | | | |
| Padua . . . | 0 | 15 | 0 | | | | |
| Ischia . . . | 0 | 15 | 35 | Period reached, 29 secs. | | | |
| Rome . . . | 0 | 15 | 40 | | | | |
| Catania . . . | 0 | 15 | 47 | | | | |
| Pavia . . . | 0 | 16 | 30 | | | | |
| Strassburg . . | 0 | 11 | 15 | S.W.–N.E. pendulum | | | |
| Nicolaiew . . | 0 | 13 | 1 | | | | |
| Potsdam . . | 0 | 17 | 0 | | | | |
| Edinburgh . . | 0 | 32 | 0 | | | | |

At nearly all the above stations several distinct maxima were observed.

*No.* 91, March 2, 1897. (B.A. Report, 1897.)

| | H. | M. | S. | |
|---|---|---|---|---|
| Shide . . . | 21 | 48 | 11 | |
| Ischia . . . | 21 | 25 | 22 | E. and W. horizontal pendulum, 12 kgs. |
| Nicolaiew . . | 21 | 14 | 1 | |
| Potsdam . . | 21 | 22 | 0 | (about) |

March 7, 1897.

At Shide record hidden by small tremors.

| | H. | M. | S. | |
|---|---|---|---|---|
| Rocca di Papa . . . . . . . . | 4 | 51 | 0 | (about) |
| Tokio . . . . . . . . . . | 6 | 24 | 46 | |

*No.* 93, March 16, 1897. (B.A. Report, 1897.)

| | H. | M. | S. | | M. |
|---|---|---|---|---|---|
| Shide . . . . . . . . | 7 | 36 | 27 | Duration . . | 29 |
| Nicolaiew . . . . . . . | 6 | 31 | 1 | | |

*No.* 96, March 23, 1897.

On this day the following cables were reported as having been interrupted:—Tenedo-Dardanelles, Malta-Alexandria, Emden-Vigo (Bay of Biscay), and the Aden-Zanzibar. A shock was also reported from Montreal.

A small disturbance was noted at Shide at 4 hrs. 19 mins. 12 secs. P.M., but it is not likely that it was connected with any of the above events.

*No.* 97, May 5, 1897.

| | H. | M. | S. | |
|---|---|---|---|---|
| Shide . . . . | 22 | 44 | 20 | Small |
| Nicolaiew . . . | 22 | 12 | 0 | With maximum at 22 hrs. 27 mins., which probably corresponds with the Shide record |

Not recorded in Italy.

*No.* 98, *May* 9, 1897.

It is remarkable that this earthquake, with two maxima and a range of motion of 6 mm., does not appear to have been recorded in Europe. I should be inclined to place its origin west of Great Britain.

*No.* 99, *May* 13, 1897.

| | H. | M. | S. | |
|---|---|---|---|---|
| Shide . . . . . . . . . . | 12 | 16 | 24 | Moderate |
| Nicolaiew . . . . . . . . . | 12 | 2 | 0 | Very large |

Apparently not recorded in Italy. It most likely originated to the east of Russia (see No. 97).

*No.* 100, May 23, 1897.

In Tokio, on the above date, a long, slow earthquake was felt at 12 hrs. 23 mins. G.M.T. In Hakodate and Sendai the times given are 12 hrs. 20 mins. and 12 hrs. The time records render it probable that the origin was nearer to Sendai than to the other places; whilst the character of the motion recorded in Tokio and Hakodate makes it probable that the focus of the disturbance would be 200 or 300 miles from those places.

With this assumption the time at the origin, which is likely to be in the Tuscarora Deep, would be about 2 mins. 30 secs. earlier than the Tokio record. The time registers are therefore as follows :—

| | H. | M. | S. | | ° | M. | S. |
|---|---|---|---|---|---|---|---|
| Time of *origin* . . . | 12 | 20 | 30 | | | | |
| Nicolaiew . . . . | 12 | 48 | 0 | Time to travel | 76 | 27 | 30 |
| Ischia . . . . | 13 | 7 | 9 | " " " | 89 | 36 | 39 |
| Shide . . . . | 13 | 15 | 20 | " " " | 86 | 54 | 50 |
| Rocca di Papa . . | 13 | 17 | 10 | " " " | 89 | 56 | 40 |
| Catania . . . . | 13 | 20 | 6 | " " " | 91 | 59 | 36 |

It will be observed that the times taken to travel from the origin, with one exception, increase with the distance of the same to the four observing stations.

From the magnitude of these intervals it is not unlikely that only the maxima phases of motion have been recorded, the *preliminary tremors* having been so small that they are not shown upon the seismograms.

*Velocity Table.*

| — | Arc | Chord | Velocity in km. per sec. *on* Arc | Velocity in km. per sec. *on* Chord |
|---|---|---|---|---|
| Nicolaiew . . . . | 76° = 8436 km. | 7829 km. | 5·1 | 4·7 |
| Ischia . . . . . | 89° = 9879 " | 8910 " | 4·5 | 4 |
| Shide . . . . . | 86° = 9546 " | 8668 " | 2·8 | 2·6 |
| Rocca di Papa . . . | 89° = 9879 " | 8910 " | 2·9 | 2·6 |
| Catania . . . . . | 91° = 10101 " | 9069 " | 2·8 | 2·5 |

*No.* 101, May 24, 1897.

| | H. | M. | S. | |
|---|---|---|---|---|
| Nicolaiew (23rd) . . . . . . . . | 23 | 57 | 0 | Large |
| Shide. . . . . . . . . . . | 0 | 18 | 59 | Moderate |
| Catania . . . . . . . . . . | 0 | 51 | 46 | Small |

Also recorded at other stations in Italy.

*No.* 104, June 3, 1897.

| | H. | M. | S. |
|---|---|---|---|
| Catania | 9 | 53 | 42 |
| Rocca di Papa | 9 | 54 | 30 |
| Shide | 9 | 57 | 18 |
| Edinburgh | 10 | 57 | 0 |

Nicolaiew not working. Also recorded at other stations in Italy. At Shide there are three maxima phases of movement.

*No.* 105, June 12, 1897.

This earthquake is one which created so much destruction in Assam that it is intimated, in order to repair roads and buildings of the Public Works Department only, more than thirty-five lakhs of rupees will be required. The total cost of the earthquake is probably many times this sum. To meet the expenditure for the restoration of roads, &c., application has been made for a grant from the Imperial revenues, and we have here an illustration, which is repeated yearly, of the manner in which an earthquake in a distant country may affect directly or indirectly the finances of people in this country. To mitigate the effects of these disasters it is necessary that the ordinary practice of the engineer and builder should be modified, and to this end I am glad to say that this Association has lent support by the publication of several reports bearing upon construction in earthquake countries. The more important of these were issued in 1889 and 1891, and the substance of them has been most carefully considered in connection with the reconstruction of railways and other works now in progress in North-eastern India.

This earthquake, which had its origin in a well-known seismic district, is probably the most severe and disastrous which, during historical times, has been experienced in this region. One evidence of this is the snapping and overturning of a number of ancient monoliths in the Khási Hills. J. C. Arbuthnott, Deputy Commissioner of this district, who describes these stones, says :—'It would possibly give people in England an idea of the severity of the shock were the Druidical stones at Stonehenge and Stennis, in Orkney, similarly overthrown or broken in two.' Similar evidence is found in the destruction of a stone bridge in the Kámrúp district of very great antiquity.

*Records.*—In the Isle of Wight, strange to say, the movements of the ground commenced whilst the photographic film was being renewed, an operation that only happens once a week. The time record, therefore, only refers to maxima phases of motion and those which followed.

The greatest range of motion was 15 mm., corresponding to a change in slope of about five seconds.

A horizontal pendulum recording N.-S. motion on smoked paper indicated a maximum range of motion of 10 mm. and a period of 15 seconds. The following are the time records :—

| | H. | M. | S. | |
|---|---|---|---|---|
| Shide | 11 | 29 | 10 | Max. The preliminary tremors exceed 10 minutes ; therefore the commencement may have been 11 hrs. 19 mins. |
| Catania | 11 | 17 | 22 | |
| Rocca di Papa | 11 | 18 | 0 | |
| Edinburgh | 11 | 18 | 0 | |
| Strassburg | 11 | 18 | 32 | |
| Batavia | 11 | 16 | 40 | By electrometer disturbance. |

*Velocity of Propagation :*

Time at origin, 11 hrs. 5 mins. 1 sec.

| | | | M. | S. | Velocity on arc. Km. | Velocity on chord. Km. |
|---|---|---|---|---|---|---|
| Time to reach | Catania . . | 64° | 12 | 21 | 9·5 | 9·0 |
| | Rocca di Papa | 65° | 13 | 59 | 8·6 | 8·1 |
| | Edinburgh . | 71° | 13 | 59 | 9·3 | 8·8 |
| | Strassburg . | 66° | 13 | 31 | 9·0 | 8·5 |
| | Shide . | 72° | 14 | 59 | 8·8 | 8·2 |

The maximum angular tilting, as indicated on the photographic film, would be about five seconds of arc.

Since writing the above several papers bearing on this earthquake have been received. From one, by Dr. G. Agamennone,[1] I have combined two tables giving the velocities of propagation on arcs of the preliminary tremors (P.T.s) and the long waves (L.W.s), and added notes respecting the character of the instruments yielding the records on which these determinations were made.

| Distance from Epicentre Km. | Observing Station | Time G.M.T. of P.T.s (H. M. S.) | Velocity of P.T.s. Kms. per sec. | Velocity of L.W.s. Kms. per sec. | Instrument H.P.=Horizontal Pendulum |
|---|---|---|---|---|---|
| 400 | Calcutta . . | 11 4 6 or „ 7 0 | — — | — — | — |
| 5980 | Petersburg . | „ 17 0 | 8·0 or 9·3 | 2·59 or 2·78 | H.P. photographic |
| 7020 | Potsdam . . | „ 17 [illegible] | 8·9 „ 11·0 | — — | H.P. photographic |
| 7150 | Catania . . | „ 17 4 | 8·8 „ 10·8 | 2·51 „ 2·65 | Long pendulum writing |
| 7150 | Portici . . | „ 17 9 | 8·5 „ 10·3 | 2·55 „ 2·69 | — |
| 7170 | Mineo . . | „ 16 0 | 9·9 „ 12·5 | — — | — |
| 7170 | Ischia . . | „ 17 2 | 9·0 „ 11·1 | 2·63 „ 2·78 | H.P. writing |
| 7220 | Spinea . . | „ 18 6 | 8·1 „ 9·8 | — — | — |
| 7240 | Padua . . | „ 17 0 | 9·2 , 11·4 | 2·66 „ 2·81 | Pendulum writing |
| 7250 | Velletri . . | „ 17 0 | 9·2 „ 11·4 | — — | — |
| 7250 | Rocca di Papa . | „ 17 5 | 8·9 „ 10·9 | 2·66 „ 2·82 | H.P. writing |
| 7260 | Rome . . | „ 17 1 | 9·2 „ 11·3 | 2·67 „ 2·82 | Long pendulum writing |
| 7310 | Florence . . | „ 18 0 | 8·6 „ 10·5 | — — | — |
| 7330 | Wilhelmshaven. | „ 18 9 | 8·1 „ 9·7 | 2·52 „ 2·66 | H.P. photographic |
| 7390 | Livorno . . | „ 17 0 | 9·4 „ 11·6 | — — | — |
| 7440 | Pavia . . | „ 18 2 | 8·6 „ 10·5 | 2·73 „ 2·90 | — |
| 7560 | Utrecht . . | „ 17 0 | 9·6 „ 11·9 | 2·37 „ 2·49 | Magnetometer |
| 7700 | Grenoble . . | „ 19 1 | 8·4 „ 10·1 | — — | — |
| 7840 | Paris . . | „ 27 6 | 5·4 „ 6·0 | — — | Magnetometer |
| 7970 | Edinburgh . | „ 18 0 | 9·4 „ 11·5 | 2·78 „ 2·93 | Bifilar pendulum photographic |
| | | Mean | 8·3 or 10·6 | 2·61 or 2·76 | |

[1] *Rend. della R. Accad. dei Lincei*, vol. vii. 1889, pp. 265–271.

It is worthy of note that we have here instances where higher velocities have been obtained from the records of instruments with frictional writing indices than from those where the records have been photographic, from which it must be inferred that the former indicated earlier phases of motion than the latter.

At Rome the long waves had a period of 10 seconds and a maximum amplitude of 12″. The complete length of these waves, as computed from the above data, would be 54 kms., and the height of their crests about half a metre.

When in Italy (see last section of this report) I saw the original seismograms of this earthquake at nearly all the stations I visited.

The preliminary tremors and the greater portion of the succeeding heavy motion, as given by two different instruments, are reproduced (figs. 1, 2 and 3) from the 'Bollettino della Società Sismologica Italiana,' vol. iii. No. 9. They are appended to a paper by Dr. Cancani, describing his horizontal pendulums and the Assam earthquake. The upper figures show the E.–W. and the N.–S. motion as recorded by the large horizontal pendulums (for a description of which see p. 265). The lower figure gives the corresponding motion, as obtained from an ordinary pendulum of 250 kgs. and 15 m. in length, the movements of which are multiplied 12·5 times. The original diagrams are about two-and-a-half times greater than the present reproduction.

The horizontal pendulums when writing have a complete period of 22 seconds. With the Indian earthquake the maximum range of motion was for the N.–S. component 5·5 cm., and for the E.–W. component 4 cm.

The maximum change in the vertical for the N.–S. component was 13″. The 15 m. pendulum showed a change of 12″, whilst with a third instrument, a simple pendulum, 7 m. in length, it was 10″. For the large waves the complete period was 18 seconds. For these waves, with a velocity of 2·7 kms. per sec., their length becomes 48·6 kms.

If $l$=length of wave, and $a$=the maximum angle of tilting, then height of a wave $= \frac{l}{2\pi} \tan a = 45$ cm.

*No.* 106, *June* 12, 1897.

| | H. | M. | S. | |
|---|---|---|---|---|
| Shide . . . . | 19 | 53 | 19 | Duration 10 mins. |
| Strassburg . . . | 19 | 23 | 27 | to 8 hrs. 35 min. 7 secs. with maximum at 7 hrs. 51 mins. 33 secs. and 8 hrs. 0 min. 31 secs. |

Not recorded in Italy or Russia.

*No.* 107, *June* 13, 1897.

| | H. | M. | S. | | M. |
|---|---|---|---|---|---|
| Shide . . . . . . . . . | 7 | 39 | 33 | Duration | 7 |
| Strassburg . . . . . . . . | 7 | 28 | 55 | | |

Not recorded in Italy or Russia.

*No.* 112, *June* 24, 1897.

A disturbance was recorded in Ischia, Padua, and Rome, but it commenced about 20 hrs. 30 mins., and not at 19 hrs. 34 mins. 53 secs., as noted at Shide.

FIG. 1.—Rocca di Papa. Pendolo orizontale E.-W. Terremoto delle Indie, Provincia di Assam e Bengal, 12 *Giugno*, 1897.

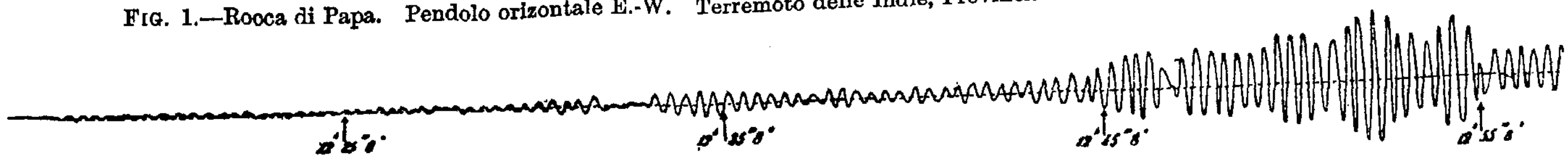


FIG. 2.—Terremoto delle Indie. Rocca di Papa, 12 *Giugno*, 1897. Pendolo orizontale N.-S.

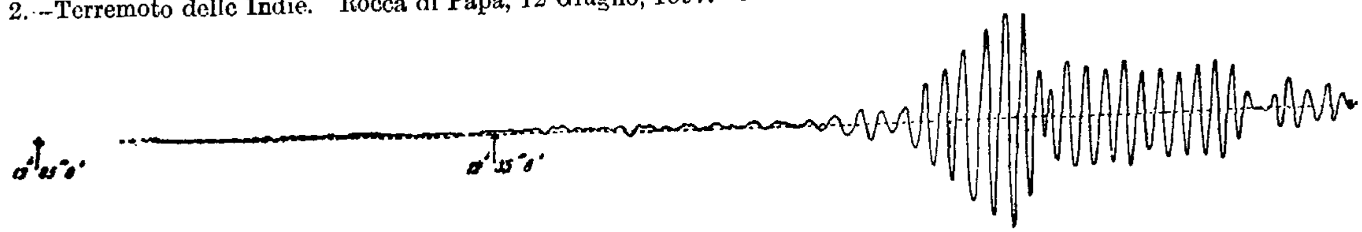
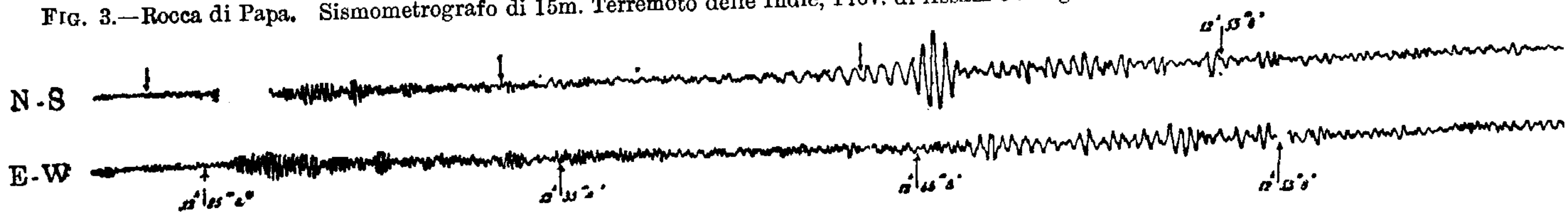


FIG. 3.—Rocca di Papa. Sismometrografo di 15m. Terremoto delle Indie, Prov. di Assam e Bengal. 12 Giugno, 1897. (Adolfo Cancani.)



*No.* 113, June 30, 1897.

| | H. | M. | S. |
|---|---|---|---|
| Shide | 4 | 39 | 33 |
| Nicolaiew | 3 | 50 | 0 |

Not recorded in Italy.

*No.* 114, June 30, 1897.

| | H. | M. | S. |
|---|---|---|---|
| Shide | 15 | 0 | 2 |
| In Italy about | 14 | 50 | 0 |

Origin Epirus.

*No.* 115, July 17, 1897.

| | H. | M. | S. |
|---|---|---|---|
| Shide | 7 | 57 | 9 |
| Nicolaiew | 7 | 48 | 0 |

Not recorded in Italy.

*No.* 116, July 21, 1897.

| | H. | M. | S. | | M. | S. |
|---|---|---|---|---|---|---|
| Shide | 13 | 33 | 32 | Preliminary tremors | 7 | 0 |
| Nicolaiew | 13 | 43 | 0 | " " | 4 | 0 |
| Catania | 13 | 39 | 4 | " " | 1 | 23 |
| Rocca di Papa | 13 | 50 | 0 (maximum) | | | |
| Edinburgh | 13 | 40 | 0 | | | |

Also noted at other stations in Italy.

*No.* 117, July 22, 1897.

Origin Japan:

| | H. | M. | S. | |
|---|---|---|---|---|
| Shide *before* | 11 | 20 | 0 | |
| Rocca di Papa | 11 | 26 | 0 (maximum) | |
| Catania | 9 | 4 | 58 (exact commencement lost) | |
| Nicolaiew | 9 | 52 | 0 | |
| Tokio | 9 | 31 | 44 | Duration 4 mins. 34 secs. Slow movement. |

*No.* 118, August 2, 1897.

| | H. | M. | S. | |
|---|---|---|---|---|
| Shide | 15 | 46 | 39 | All small, and it is likely that the records refer to different shocks. |
| Catania | 15 | 0 | 17 | |
| Nicolaiew | 15 | 29 | 0 | |

*No.* 119, August 5, 1897.

This earthquake was felt over the whole of Japan, from Nemuro, in the north-east, to Nagasaki, more than 1,000 geographical miles distant, in the south-west. The following notes taken from the 'Japan Weekly Mail' of Saturday, August 7, give the times at which movements were observed at different towns lying between the above-mentioned places. These times are expressed as Japan mean time, which is exactly nine hours in advance of Greenwich mean time.

The earthquake of Thursday morning was of very long duration, but fortunately, owing to its gentleness, no damage was done. Starting at 9 hrs. 11 mins. 56 secs. A.M., the motion continued for 7 mins. 59 secs., the vibrations moving from E. to W. Four minor shocks were felt at 9.23, 10, and 11.31 o'clock the same morning.

*Hakone*, 9 A.M. (August 5).

A strong earthquake was felt here this morning at about 9.20 o'clock It lasted for several minutes, but was quite regular (horizontal) in its movement. The Japanese say that they seldom have such a long or strong earthquake here, and they rushed out of their houses very quickly.

*Shizuoka* (August 5).

A slight earthquake was felt here at 9.20 A.M.

*Sendai* (August 5).

A strong earthquake occurred here this morning at 9 o'clock.

*Mito* (August 5).

A strong gale swept over the locality last night, and this morning a sharp earthquake was felt here.

*Mayebashi* (August 5).

An earthquake occurred here this morning at half-past 9 o'clock.

*Uyeda, Shinshu* (August 5).

An earthquake was felt here this morning at half-past 9 o'clock.

The earthquake is also reported from :—

*Gifu*, 7.57 A.M., slight.
*Nagasaki*, 8.06 A.M., slight.
*Kumagaya*, 9.07 A.M., strong.
*Ishinomaki*, 9.10 A.M., strong.
*Mito*, 9.10 A.M., strong.
*Aomori*, 9.11 A.M., strong.
*Yamagata*, 9.11 A.M., strong.
*Mayebashi*, 9.11 A.M., strong.
*Niigata*, 9.12 A.M., strong.
*Kofu*, 9.12 A.M., strong.
*Fukushima*, 9.10 A.M., feeble.
*Nagano*, 9.11 A.M., feeble.
*Gifu*, 9.11 A.M., feeble.
*Utsunomiya*, 9.12 A.M., feeble.
*Tokio*, 9.12 A.M., feeble.
*Yokosuka*, 9.12 A.M., feeble.
*Nagoya*, 9.13 A.M., feeble.
*Akita*, 9.20 A.M., feeble.
*Choshi*, 9.12 A.M., slight.
*Numazu*, 9.12 A.M., slight.
*Nemuro*, 9.12 A.M., slight.
*Kushiro*, 9.13 A.M., slight.
*Hachiki*, 9.15 A.M., slight.

By reference to the catalogue of earthquakes recorded at the Central Meteorological Observatory in Tokio, p. 190 (Nos. 1901 to 1908), it will be seen that on the 5th the first disturbance was followed by seven smaller disturbances.

From these reports, and from private correspondence with Japan, we learn that the movements were slow. This means that the period of the earth waves would be about three seconds. This being so, experience teaches us that places like Tokio were at a distance of 200 or 300 miles from the origin of the disturbance.

The fact that movements commenced at and near to Tokio at about the same time they commenced at and near to Nemuro, whilst at Ishinomaki, Mito, Aomori, Yamagata, and other places lying between Tokio and Nemuro, movements commenced one or two minutes earlier, leads to the conclusion that the origin was off the east coast of Japan.

From the time observations generally, the locus sought for may be placed near to the centre of a circle which would approximately pass through Tokio, Niigata, and Nemuro. This would lie about 150 miles east of Sendai, at a depth of 4,000 fathoms, exactly at the bottom of the Nippon slope of the Tuscarora Deep. This is practically the same origin as that given for the shock of June 15, 1896,[1] as it is for many other disturbances which have shaken the whole of the Japanese islands. Facts to be noticed about this particular group of earthquakes are that they are the largest, that they originate along the base of the steepest slope, and that it is only occasionally that they are accompanied by sea waves. The disturbance of June 15, 1896, was accompanied by waves which resulted in the loss of nearly 30,000 lives, whilst the shaking of the ground was barely perceptible at Tokio. The earthquake about which I now write as a producer of earth waves which could be felt was much more marked than that of June 15, and yet sea waves were not recorded. The inference is that the earthquake of August 5 was not accompanied by any marked displacement of large bodies of material at the bottom of the ocean, and its origin was practically beneath the sub-oceanic crust. It is therefore possible that we have in the Tuscarora earthquakes examples of disturbances due to accelerations in the secular flow of a quasi-rigid subterranean material under the influence of continental load. If this is the case we should expect to find records of local magnetic perturbation.

*Velocity of Propagation of Earth Waves.*

Assuming the origin of the earthquake to have been 250 geographical miles to the north-east of Tokio, and the wave to have been propagated to that place at a rate of about 8,000 feet per second, then the time at which the earthquake originated in G.M.T. was August 5, 9 mins. 23 secs.

*G.M.T.—Times at which Preliminary Tremors commenced in Europe.*

| | H. M. S. | | M. S. |
|---|---|---|---|
| Shide . . . . | 0 22 35 | Time to travel . . . | 13 12 |
| Rocca di Papa . . | 0 32 40 | ,, ,, . . . | 23 17 |
| Catania . . . | 0 24 35 | ,, ,, . . . | 15 12 |
| Nicolaiew . . . | 0 17 0 | ,, ,, . . . | 7 37 |
| Edinburgh . . . | 1 2 30 | ,, ,, (Large waves ?) | 53 7 |

*Apparent Velocity of Preliminary Tremors.*

| — | Distance | | Velocity in km. per sec. | |
|---|---|---|---|---|
| | On Arc | On Chord | On Arc | On Chord |
| Nicolaiew . . . . . | 76° = 8436 km | 7829 | 18 ? | 17 ? |
| Shide . . . . . | 86° = 9546 ,, | 8668 | 11 | 10 |
| Rocca di Papa . . . . | 89° = 9879 ,, | 8910 | 7 | 6·3 |
| Catania . . . . . | 91° = 10101 ,, | 9069 | 11 | 9·9 |

No. 120, August 16, 1897.

| | H. | M. | S. | |
|---|---|---|---|---|
| Shide . . . . . | 8 | 6 | 29 | |
| Italy about . . . | 8 | 15 | 0 | at Catania, Ischia, Rome, Rocca di Papa. |
| Tokio . . . . . | 7 | 53 | 33 | Duration 3 mins. Slow movement. |

[1] Also see *British Association Report*, 1896, p. 153.

*No.* 122, August 26, 1897.

| | H. | M. | S. |
|---|---|---|---|
| Shide | 17 | 1 | 41 |
| Nicolaiew | 16 | 32 | 0 |
| Rocca di Papa | 14 | 46 | 30 |
| Tokio | 16 | 8 | 46 |

*No.* 123, August 26, 1897.

| | H. | M. | S. |
|---|---|---|---|
| Shide | 21 | 40 | 30 |
| Nicolaiew | 21 | 40 | 0 |

And at several places in Italy.

| | | | |
|---|---|---|---|
| Tokio | 21 | 19 | 20 |

*No.* 124, August 26, 1897.

| | H. | M. | S. |
|---|---|---|---|
| Shide | 22 | 13 | 14 |
| Rocca di Papa | 22 | 8 | 30 |

And other stations in Italy.

*No.* 131, September 17, 1897.

| | H. | M. | S. | |
|---|---|---|---|---|
| Shide | 15 | 59 | 58 | Preliminary tremors. |
| Catania | 15 | 15 | 50 | Small |
| Edinburgh | 15 | 55 | 0 | |
| Nicolaiew | 15 | 40 | 0 | |
| Rocca di Papa | 15 | 50 | 0 | |

And other Italian stations.

Origin probably Tashkent.

*No.* 132, September 17, 1897.

| | H. | M. | S. | | M. |
|---|---|---|---|---|---|
| Shide | 17 | 59 | 58 | Preliminary tremors. | 8 |
| Edinburgh | 18 | 2 | 0 | | |
| Nicolaiew | 18 | 0 | 0 | Details lost | |
| Rocca di Papa | 17 | 48 | 0 | | |

And other Italian stations.

The similarity of the Shide seismograms for Nos. 131 and 132 suggests that they originated at or near the same place.

*No.* 133, September 20, 1897.

| | H. | M. | S. | | M. |
|---|---|---|---|---|---|
| Shide | 19 | 24 | 47 | Large. Preliminary tremors. | 40 |
| Edinburgh | 19 | 56 | 0 | | |
| Catania | 19 | 25 | 2 | Small | |
| Rocca di Papa | 19 | 25 | 0 | | |
| Nicolaiew | 19 | 23 | 30 | Very large | |

Also at other stations in Italy.

| | H. | M. | S. | |
|---|---|---|---|---|
| Batavia | 19 | 14 | 20 | by disturbance of an electrometer |

*No.* 134, September 21, 1897.

| | H. | M. | S. | | M. |
|---|---|---|---|---|---|
| Shide | 5 | 28 | 51 | Large. Preliminary tremors. | 43 |
| Edinburgh | 6 | 7 | 30 | | |
| Catania | 5 | 29 | 32 | Small | |
| Rocca di Papa | 5 | 32 | 8 | | |
| Nicolaiew | 4 | 57 | 0 | Very large | |

Also at other Italian stations.

P 2

The above earthquake evidently refers to one of two shocks which were felt in Sandakan, on the north coast of Borneo, at 1.10 P.M. local time (about 5.20 A.M. G.M.T.) on September 21. It was sufficiently severe to crack a house and stop the town clock.

These and other shocks accompanied the throwing up of a volcanic island in E.L. 115° and N.L. 5° 14′, about which on October 25 the 'Times' writes as follows :—

'A NEW VOLCANIC ISLAND.—The 'Straits Times' of September 29 states that, according to telegraphic advices from British North Borneo, an earthquake was felt at Kudat on September 21, as also a slight tremor at several places along the coast. About the same time a new island was thrown up from the sea between Mempakul and Lambeidan, 50 yards from the mainland, opposite Labuan. The island is of clay and rocks, and measures 200 yards long by 150 yards broad and 60 feet high. The island appears to be increasing in size, and emits inflammable gas in several places, with a strong smell of petroleum gas. The earthquake was not felt at Labuan.'

Comparing this disturbance 134 with 133, both which are large at Shide and Nicolaiew but small in Italy, we have an example of earthquakes apparently from the same origin, and as measured by the distance to which they propagated their vibrations of equal intensity, but which had very different effects locally. The former only slightly disturbed a magnetograph in Batavia, 13° or 1,400 kms. distant, whilst the second created marked disturbances in such instruments at Batavia and other places, p. 243. Also the second was felt severely in Kudat and Sandakan (but not at Labuan), and is reported in the newspapers, whilst the first is passed without notice.

The similarity of the Shide seismograms for 133 and 134 also suggests that these shocks originated at or near the same locality.

*No.* 135, September 21, 1897.

| | H. | M. | S. | | H. | M. | S. |
|---|---|---|---|---|---|---|---|
| Shide | 11 | 36 | 44 | to | 13 | 20 | 20 |

About 13 hours in Central Italy there was a violent earthquake, which was recorded at all the observatories in Italy. It is hardly likely that this is represented by the latter portion of the slight disturbances at Shide.

*No.* 138, October 2, 1897.

| | H. | M. | S. | | | H. | M. | S. | |
|---|---|---|---|---|---|---|---|---|---|
| Shide | 13 | 36 | 39 | Moderate | Duration | 0 | 27 | 0 | |
| Catania | 13 | 31 | 51 | | „ | 0 | 32 | 11 | |
| Nicolaiew | 12 | 56 | 30 | Very large | „ | 1 | 36 | 0 | |

Also at Rome.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Tokio | 12 | 45 | 19 | „ „ | „ | 0 | 3 | 25 | by seismograph |

*No.* 139, October 3, 1897.

| | H. | M. | S. | |
|---|---|---|---|---|
| Shide | 15 | 7 | 9 | |
| Edinburgh | 14 | 58 | 0 | Slight tilt to N. |

*No.* 140, October 19, 1897.

| | H. | M. | S. | | M. | | H. | M. | S. |
|---|---|---|---|---|---|---|---|---|---|
| Shide | 0 | 6 | 52 | Preliminary tremors. | 41 | Duration | 2 | 30 | 0 |
| Edinburgh | 0 | 28 | 0 | | | ,, | 0 | 32 | 0 |
| Catania | 0 | 6 | 36 | Small | | ,, | 0 | 52 | 42 |
| Rocca di Papa | 0 | 5 | 30 | | | ,, | 1 | 9 | 30 |
| Nicolaiew | 0 | 13 | 0 | Very large. P.T.s | 7 | ,, | 3 | 1 | 0 |

Also at Rome and Ischia.

*No.* 141, October 20, 1897.

| | H. | M. | S. | | M. | | H. | M | S. |
|---|---|---|---|---|---|---|---|---|---|
| Shide | 14 | 43 | 29 | Preliminary tremors. | 42 | Duration | 2 | 33 | 0 |
| Edinburgh | 15 | 20 | 0 | | | ,, | 0 | 13 | 0 |
| Catania | 14 | 49 | 26 | Small | | | | | |
| Rocca di Papa | 15 | 0 | 0 | | | ,, | 2 | 0 | 0 |
| Nicolaiew | 14 | 49 | 0 | Very large. P.T.s | 11 | ,, | 3 | 4 | 0 |

Also at Rome and Ischia.

The similarity of the Isle of Wight seismograms for Nos. 140 and 141 together, that in each case the Nicolaiew instrument commenced its records 6 or 7 minutes after the Isle of Wight, indicate that these earthquakes had a similar origin.

*No.* 142, October 23, 1897.

| | H. | M. | S. | |
|---|---|---|---|---|
| Shide | 3 | 19 | 0 | |
| At about | 3 | 15 | 0 | a disturbance was noted at Catania, Ischia, and Rome. |

*No.* 146, November 14, 1897.

| | H. | M. | S. | | M. |
|---|---|---|---|---|---|
| Shide | 14 | 53 | 35 | Duration | 22 |
| Edinburgh | 15 | 29 | 0 | Tilt to N. | |

Not recorded in Europe.

*No.* 152, November 25, 1897.

| | H. | M. | S. | | H. | M. |
|---|---|---|---|---|---|---|
| Shide | 10 | 1 | 48 | Duration | 2 | 0 |
| Catania | 10 | 19 | 3 | ,, | 1 | 23 |

*No.* 153, December 11, 1897.

| | H. | M. | S. | | | H. | M. | S. |
|---|---|---|---|---|---|---|---|---|
| **Shide** | 10 | 4 | 31 | Small | Duration | 0 | 45 | 0 |
| **Catania** | 9 | 51 | 28 | P.T.s 14h. 21m. small | ,, | 1 | 20 | 54 |
| **Nicolaiew** | 10 | 9 | 0 | Moderate | ,, | 1 | 10 | 0 |
| **Tokio** | 9 | 40 | 49 | Slight | | | | |

*No. 155, December 17, 1897.*

| | H. | M. | S. | | H. | M. | S. | |
|---|---|---|---|---|---|---|---|---|
| **Shide** | 18 | 30 | 0 | Up to Dec. 18 | 10 | 30 | 0 | Slight |

**Italy, a strong shock,** Dec. 18 about 7.30 A.M.

*No.* 156, December 28, 1897.

| | H. | M. | S. | | | M. | S. | | M. |
|---|---|---|---|---|---|---|---|---|---|
| **Shide** | 20 | 54 | 21 | Moderate. | P.T.s | 8 | 0 | Duration | 24 |
| **Nicolaiew** | 20 | 53 | 0 | Small | | | | ,, | 29 |
| **Toronto** | 20 | 24 | 37 | ,, | P.T.s | 7 | 10 | ,, | 35 |

It will be observed that we have here the records from three instruments not controlled by the friction of writing pointers, and therefore fairly comparable.

*No.* 157, December 29, 1897.

| | H. | M. | S. | | M. | S. | | H. | M. | S. |
|---|---|---|---|---|---|---|---|---|---|---|
| Shide . . | 11 | 40 | 48 | Large P.T.s | 19 | 49 | Duration . | 1 | 22 | 28 |
| Catania . . | 11 | 29 | 10 | | | | " . | 1 | 30 | 50 |
| Rocca di Papa . | 11 | 56 | 0 | | | | " . | 0 | 27 | 0 |
| Nicolaiew. . | 11 | 47 | 0 | Small | | | " . | 2 | 5 | 0 |
| Toronto . . | 11 | 32 | 29 | No preliminary tremors | | | " . | 1 | 10 | 0 |
| Port-au-Prince . | 11 | 22 | 7 | Near the origin | | | | | | |

Also at other stations in Italy.

In connection with this earthquake Professor R. F. Stupart, of Toronto, sends me the following note taken from the 'U.S. Monthly Weather Review,' January 1898 :—

'*December* 29*th*. 6 hrs. 32 mins. 43 secs. A.M., Port-au-Prince, Hayti, W.I.

'Professor T. Scherer reports as follows :—"A severe earthquake was experienced at Port-au-Prince, lasting 1 minute and 31 seconds. The following are the conclusions to be drawn from the curves traced by the Secchi seismograph at the meteorological observatory of the College of St. Martial :—

'"The entire phenomenon consisted of five consecutive shocks, the total duration of which was 48 seconds, and of a series of feeble movements very perceptible to an attentive observer. The first shock lasted 8 seconds : it began from east-north-east and from west-south-west. The vertical component was quite strong at about the fifth second. The movement immediately began with more force in the horizontal direction and less in the vertical : this lasted 11 seconds, and the direction from which it came was more toward the east. The third shock lasted 3 seconds, and was characterised by a very regular oscillatory movement. The first shock was the strongest, lasted 10 seconds, began from the north-east, and died away in the south-west, with a vertical component that was scarcely appreciable. All the other movements, after the forty-eighth second, were feeble with the same horizontal direction. During all this time the seismic pendulum described ellipses in the sand whose major axes varied from north-east through the south to south-west. The Bertelli microseismometer was for a long time agitated, and finally maintained a north-south direction.

'"The same earthquake was felt in the neighbourhood of Port-au-Prince and with the same features. It seems to have been very violent in the interior on the island of Dominica."'

This earthquake had a submarine origin, and interrupted the Cape Haytien-Puerto Plata and Puerto Plata-Martinique cables, together with the Dominican land lines.

*No.* 158, December 29, 1897, to January 1, 1898.

During this interval slight tremors were recorded at Shide. In Italy, on December 29, between 11 hrs. 30 mins. and 13 hrs., perturbations were recorded in several observations. On December 31, at about 17 hrs., a slight disturbance at Ischia and Florence was noted.

*No.* 161, January 24, 1898.

| | H. | M. | S. | | | H. | M. | S. |
|---|---|---|---|---|---|---|---|---|
| Shide | 23 | 45 | 49 | Large P.T.s 16 mins. | Duration | 0 | 33 | 0 |
| Rocca di Papa | 23 | 49 | 0 | | „ | 0 | 56 | 0 |
| Nicolaiew | 23 | 49 | 30 | Very large | „ | 0 | 37 | 30 |
| Toronto (25th) | 0 | 13 | 30 | P.T.s 13 mins. 30 secs. | | | | |

*No.* 162, January 29, 1898.

| | H. | M. | S. | | | H. | M. | S. |
|---|---|---|---|---|---|---|---|---|
| Shide | 13 | 44 | 8 | Small P.T.s 5 mins. 47 secs. | Duration | 0 | 13 | 1 |
| Catania | 14 | 4 | 41 | Large P.T.s 1 h. 2 m. 19 s. | „ | 1 | 33 | 51 |
| Rocca di Papa | 13 | 39 | 0 | | „ | 0 | 5 | 0 |
| Nicolaiew | 13 | 33 | 0 | Small | „ | 0 | 19 | 0 |

Also at other stations in Italy.

*No.* 163, January 29, 1898.

| | H. | M. | S. | | | H. | M. | S. |
|---|---|---|---|---|---|---|---|---|
| Shide | 15 | 5 | 25 | Large P.T.s 9 mins. 9 secs. | Duration | 1 | 1 | 0 |
| Edinburgh | 15 | 15 | 0 | | „ | 0 | 10 | 0 |
| Rocca di Papa | 15 | 5 | 15 | | „ | 0 | 35 | 0 |
| Nicolaiew | 15 | 4 | 0 | Very large | „ | 0 | 58 | 0 |
| Laibach | 15 | 1 | 7 | | „ | 0 | 49 | 0 |

At Shide the period of the large waves was 10 secs.

The records evidently indicate the severe earthquake in Asia Minor, respecting which London papers published the following Reuter telegram :—

'*Constantinople*, February 3, 1898.

'The earthquakes in Asia Minor continued at intervals from Saturday till Monday. At Balikesri, the military prison, two minarets and fifteen houses were totally destroyed, and every house in the town was more or less damaged. Twenty persons were killed and fifty injured.

'Considerable damage was done also at Bighadidj, Inegeul, and other villages, though with what loss of life is unknown.'

*No.* 164, February 5, 1898.

| | H. | M. | S. | | H. | M. | S. | |
|---|---|---|---|---|---|---|---|---|
| Shide | 8 | 36 | 13 | to | 9 | 19 | 28 | Record on smoked paper |

About 9 hrs. perturbations were observed in Catania, Rome, Livorne, &c.

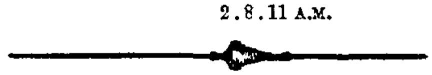
From the preceding lists and notes it appears that between March 23, 1897, and February 16, 1898, 74 earthquakes were recorded at Shide, 38 of which were also recorded in Europe or America.

The following are sketches of Seismograms obtained at Shide, Potsdam, and Toronto.

The times given are for the commencement of movements. Other phases of movement may be calculated on the assumption that for

Shide, Nos. 85 to 138, 45 mm. = 1 hour; Nos. 140 to 157, 60 mm. = 1 hour.
Potsdam, 20 mm. = 1 hour.
Toronto, 60 mm. = 1 hour.

2.8.11 A.M.



No. 85.—Shide, Feb. 13, 1897.

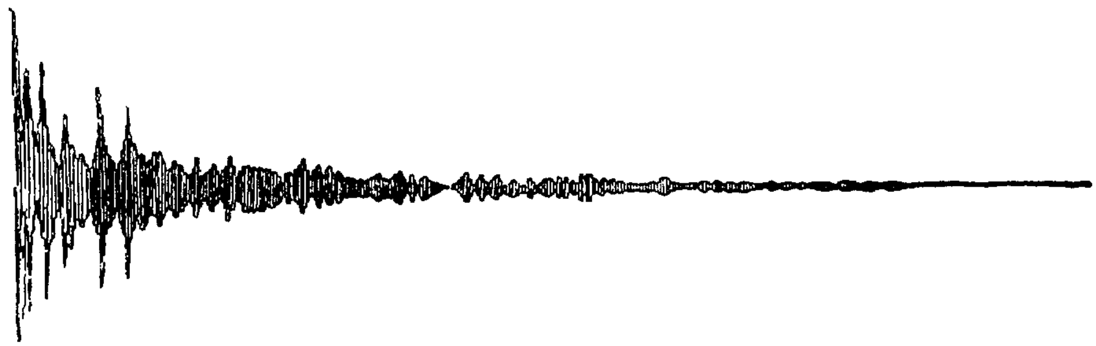
0.16.24 P.M.

No. 99.—Shide, May 13, 1897.

9.57.18 A.M.

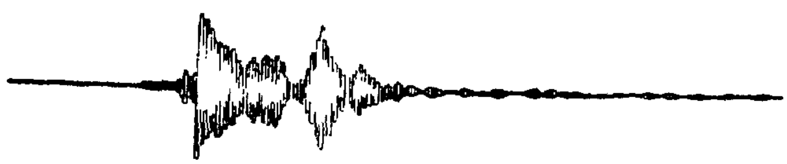
No. 104.—Shide, June 3, 1897.

0.32.51 P.M.

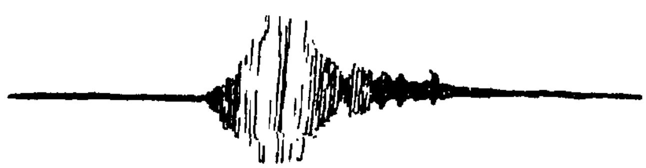


No. 105.—Shide, June 12, 1897.

1.33.32 P.M.

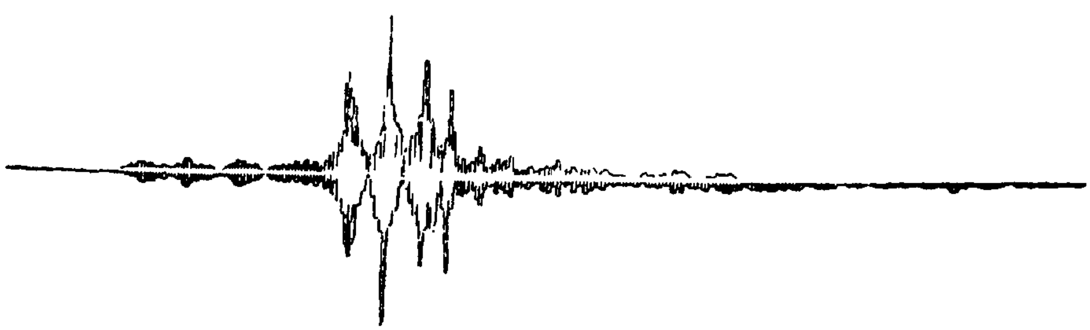


No. 116.—Shide, July 21, 1897.



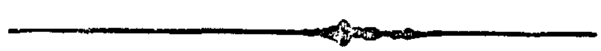
No. 116.—Potsdam.

0.22.35 A.M.

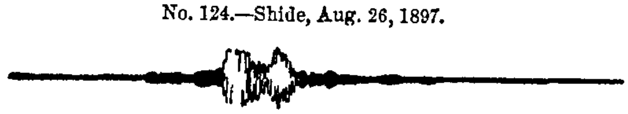


No. 19.—Shide, Aug. 5, 1897.

10.13.14 P.M.

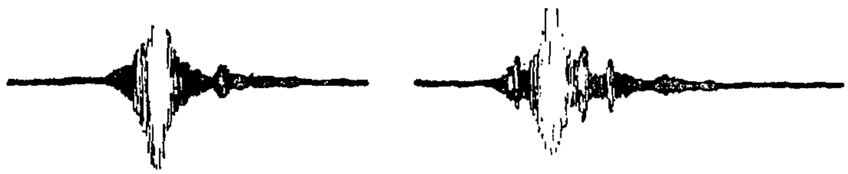


No. 124.—Shide, Aug. 26, 1897.

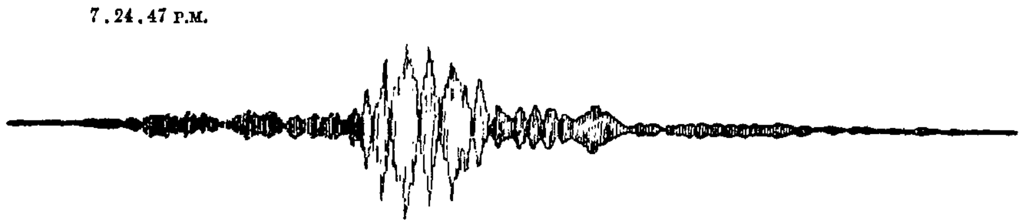


No. 124.—Potsdam.

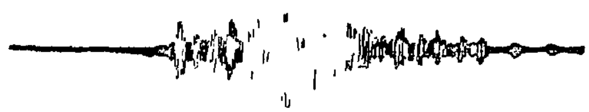

Nos. 131 and 132.—Shide, Sept. 17, 1897.



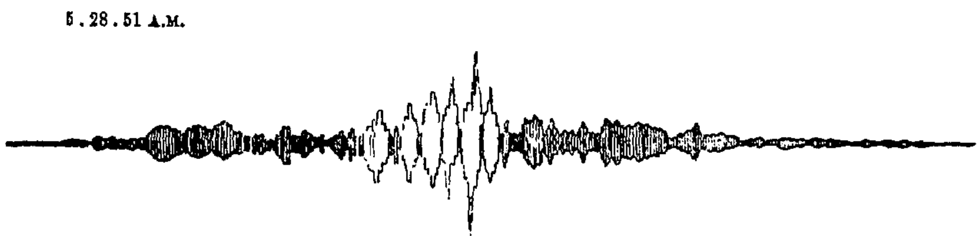
Nos. 131 and 132.—Potsdam.



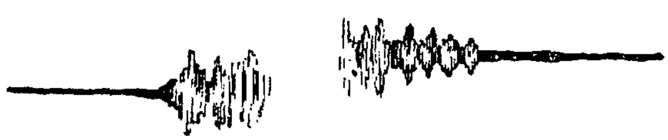

No. 133.—Shide, Sept. 20, 1897.



No. 133.—Potsdam.




No. 134.—Shide, Sept. 21, 1898.



No. 134.—Potsdam.


No. 138.—Shide, Oct. 2, 1897.

No. 138.—Potsdam.


No. 140.—Shide, Oct. 18, 1897.

No. 140.—Potsdam.

2.43.29 P.M.

No. 141.—Shide, Oct. 20, 1897.

No. 141.—Potsdam.

8.54.21 P.M.

No. 156.—Shide, Dec. 28, 1897.

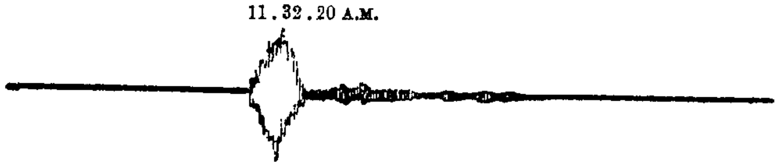
8.24.39 P.M.

No. 156.—Toronto.

11.40.48 A.M.

No. 157.—Shide, Dec. 29, 1897.

11.32.20 A.M.



No. 157.—Toronto.

## V. *On Certain Characteristics of Earthquake Motion.*

### 1. *The Character of Earth Waves near to their Origin.*

From the feelings of those who reside in earthquake districts, and more definitely from seismograms, we have learned that the movements of the ground constituting an earthquake of moderate intensity, which in an epifocal area may shake badly constructed chimneys and loosen tiles upon a roof, as observed at distances of approximately 20 or 100 miles from its origin, consist of preliminary vibrations, a shock or shocks separated by more or less irregular waves, and a series of concluding vibrations. At distances of from 100 to 200 or 300 miles the preliminary vibrations may not be felt, or even recorded, on an ordinary seismograph, and instead of a shock or shocks we obtain a record of a series of long-period but irregularly recurring waves. These movements give rise to a sensation not unlike that felt upon a floating stage rising and falling upon a swell. The movement of hanging pictures and that of seismographs indicate that an intermittent tilting is taking place. The heavy masses of metal in bracket seismographs, conical pendulums, and other instruments, no longer act as steady points, but swing fitfully with varying amplitudes from side to side, and, rather than giving records of horizontal displacement, they are roughly recording the maximum slopes of the earth waves which tilt the supporting piers.

Beyond the 300-mile limit nothing is felt, and it is seldom that an ordinary seismograph, writing with frictional indices, gives a record. Now and then, where the friction of writing pointers has been exceedingly low, records of unfelt earthquakes have been obtained from ordinary seismographs. It was the magnitude of these diagrams obtained by the writer, coupled with numerous observations made by astronomers on the movement of the bubbles in levels, the tilting of water in ponds, and kindred observations, which enabled him, in 1883, to venture the opinion that with suitable instruments the movement of all large earthquakes might be recorded in any portion of the world (see 'Earthquakes and other Earth Movements,' Int. Sci. Series, pp. 226 and 342). The ample manner in which this has been confirmed is known to all seismologists.

*Preliminary Tremors.*—The period of these, as recorded on seismographs with frictional indices, has varied between $\frac{1}{5}$ and $\frac{1}{20}$ of a second. Along paths of from 1 to 4 geographical degrees (111 to 444 kms.) the velocity is *apparently* about 2 kms. per second. This, however, is the velocity of the larger waves, which the preliminary tremors most certainly outrace. Strange to say, we know less about the difference in rate of propagation of these small movements and their larger followers over short ranges than we do over long ranges. As a working hypothesis, founded on the interval of time that elapses between the screaming of pheasants and the arrival of sensible motion and the records of seismograms, I anticipate that this interval will be found to be about 10 seconds for about every 100 kms. of travel; that is, if a shock originates at a distance of, say, 200 kms., these preliminary tremors may be noticed 20 seconds before the arrival of pronounced motion. If this is so, then the velocity of propagation for preliminary tremors over short ranges will be about 2·5 kms. per second.

If, for the time being, we accept this factor, then if $l$ is the length of a wave, $t$ its period, and $v$ its velocity, because

$$l = vt$$

with a period of $\frac{1}{20}$ second, the length of a wave is about ·125 km. (410 feet).

Their amplitudes, as shown on seismograms, are exceedingly small, say $\frac{1}{20}$ mm.

*Large Waves.*—The large waves have periods of from 1 to 2·5 seconds, which, with velocities of 2 kms. per second, would indicate lengths of 2 to 5 kms. (6,560 to 16,400 feet). The maximum amplitudes of these, which represent shocks which will shatter ill-constructed chimneys, lie between 20 and 70 mm.

*Concluding Vibrations.*—Seismograms clearly show waves having periods of from 3 to 5 seconds, the lengths of which may therefore reach as much as 10 kms. (32,800 feet).

Figures like the above, representing the length of seismic waves, although especially for the large waves we can rely upon the data for velocity and period, must yet be accepted with great caution. For the earthquake of October 28, 1891, as recorded in Tokio, it would appear that seismographs were tilted through an angle of about one-third of a degree, whilst the actual height of the waves was about 10 mm. If these measurements, referred to symmetrically, formed wave-surfaces, the conclusion is that the lengths of the waves did not exceed 20 or 40 feet ; the difference between which and, say, 1,600 feet is so great that all confidence in the determination of wave-lengths is apparently destroyed within an epifocal area, or, to be more precise, within five or six miles of an origin. Where waves can be seen rolling down a street, we are here at least certain that the distance from crest to crest of an earth-wave is measured by 10 or 20 feet rather than by hundreds or thousands of feet.

### 2. *On the Velocity of Propagation of Large Waves.*

From the table on p. 221, where we find the length of arc along which motion may have travelled, the velocity of the preliminary tremors along such a path and the duration of their movements, which is the interval of time by which they outraced the succeeding large waves, it is easy to calculate the velocity with which these waves were propagated. The results of such calculations, together with results obtained from somewhat different data by von Rebeur-Paschwitz and Dr. A. Cancani, are given in the following table :—

*Velocities of Large Waves in Km. per sec.*

| Arc | Along arc | Along chord | Von Rebeur along chord | Cancani along chord |
|---|---|---|---|---|
| ° | | | | |
| 20 | 2·1 | 2·1 | 1 to 2·5 | 2·5 |
| 60 | 2·8 | 2·7 | — | 2·7 |
| 80 | 2·9 | 2·7 | 3 to 3·5 | — |
| 110 | 3·3 | 2·8 | — | 3·1 |

### 3. *On the Character of Earth-waves after having travelled Great Distances.*

The following remarks are based on records of earthquakes obtained at distances from their origin so great that movement of the ground could not be felt, whilst ordinary seismographs failed to indicate any movement of the piers on which they rested. Many of them, for example, refer to seismograms obtained in Europe or England of earthquakes which originated at places so far distant as Japan.

#### *Preliminary Tremors.*

*Velocity.*—In the Report for 1897 (p. 173) a table is given of the highest apparent velocities with which the preliminary tremors of about seventy disturbances have been propagated over or across arcs of great circles on the earth's surface. These arcs have varied in length from about 2° to 156°. The observations on arcs of from 2° to 18° and from 70° to 85° have been fairly numerous. For arcs of intermediate length the observations were only three or four, but inasmuch as these take up their proper position on a curve of velocities, it may be assumed that they are the result of fairly accurate observations. This also applies to the two or three records on wave paths exceeding the 85° limit. In the original diagram ('Report' for 1897, p. 174) those observations which by reference to orginal records are found untrustworthy are surrounded by circles.

The general results arrived at are easily remembered. If it is assumed that motion is propagated *round* the earth, then the velocities over arcs of 20°, 30°, 40° up to about 100°, which have lengths of 2,200, 3,300, 4,000, and 11,100 kilometres, are *about* 2, 3, 4, and 11 kilometres per second. Along wave paths less than 20° the velocity of 2 kilometres per second remains constant. For arcs greater than 100° the velocity apparently increases at a rate somewhat less than the rate at which the length of the arc increases.

With the hypothesis that the vibrations travel along paths approximating to chords through the earth, then the above velocities must be reduced. The actual velocities obtained as mean values from a number of observations are given in columns 9 and 10 of the following table :—

*Table showing the Relationship between the Apparent Velocities with which Preliminary Tremors are propagated round or through the Earth, and dimensions of the same, &c. The first four Velocities are derived from Observations. The last two are inferred.*[1]

| Degrees of Arc | Length of Arc in Kms. 1°=111 Kms. | Length of Chord in Kms. Radius=6,360 Kms. | Diff. in Length of Arc and Chord in Kms. | Max. Depth of Chord in Kms. | Average Depth of Chord in Kms. | $\sqrt{\text{Max.}}$ Depth of Chord | $\sqrt{\text{Average}}$ Depth of Chord | Velocity of P.T.s in Kms. per sec. on Arc | Velocity of P.T.s in Kms. per sec. on Chord | Duration of P.T.s in mins. |
|---|---|---|---|---|---|---|---|---|---|---|
| 20° | 2220 | 2208 | 12 | 97 | 67 | 9·7 | 8·18 | 2·75 | 2·75 | 0 to 4 |
| 60° | 6660 | 6360 | 300 | 853 | 608 | 29·20 | 24·6 | 6 | 5·7 | 20 |
| 80° | 8880 | 8175 | 707 | 1487 | 1053 | 38·8 | 32·4 | 8·2 | 7·5 | 30 to 34 |
| 110° | 12210 | 10419 | 1791 | 2712 | 1977 | 52 | 44·4 | 11 | 9·3 | 41 to 43 |
| 140° | 15540 | 11952 | 3588 | 4197 | 3149 | 64·8 | 56 | 13·8 ? | 9·9 | unknown |
| 180° | 19980 | 12720 | 7260 | 6360 | 5097 | 79·6 | 71 | 17·4 ? | 11·1 | " |

It will be observed that the quantities given in the eighth column are approximately four times those in the ninth column.

In questions relating to the direction taken by a wave in passing through the earth, it must be remembered that this may not necessarily be along a chord, but in consequence of refraction follow a path that is curved.

## *Apparent Duration of Preliminary Tremors.*

The following table gives the time intervals by which preliminary tremors have outraced the longer period and larger waves constituting the main portion of various earthquake disturbances. Beneath these time records, inclosed in brackets, the distances of the various observing stations from epifocal areas are given in geographical degrees or kilometres :—

[1] See *British Association Report*, 1897, p. 174.

*Apparent Duration of Preliminary Tremors.* (m = minutes ; s = seconds.)

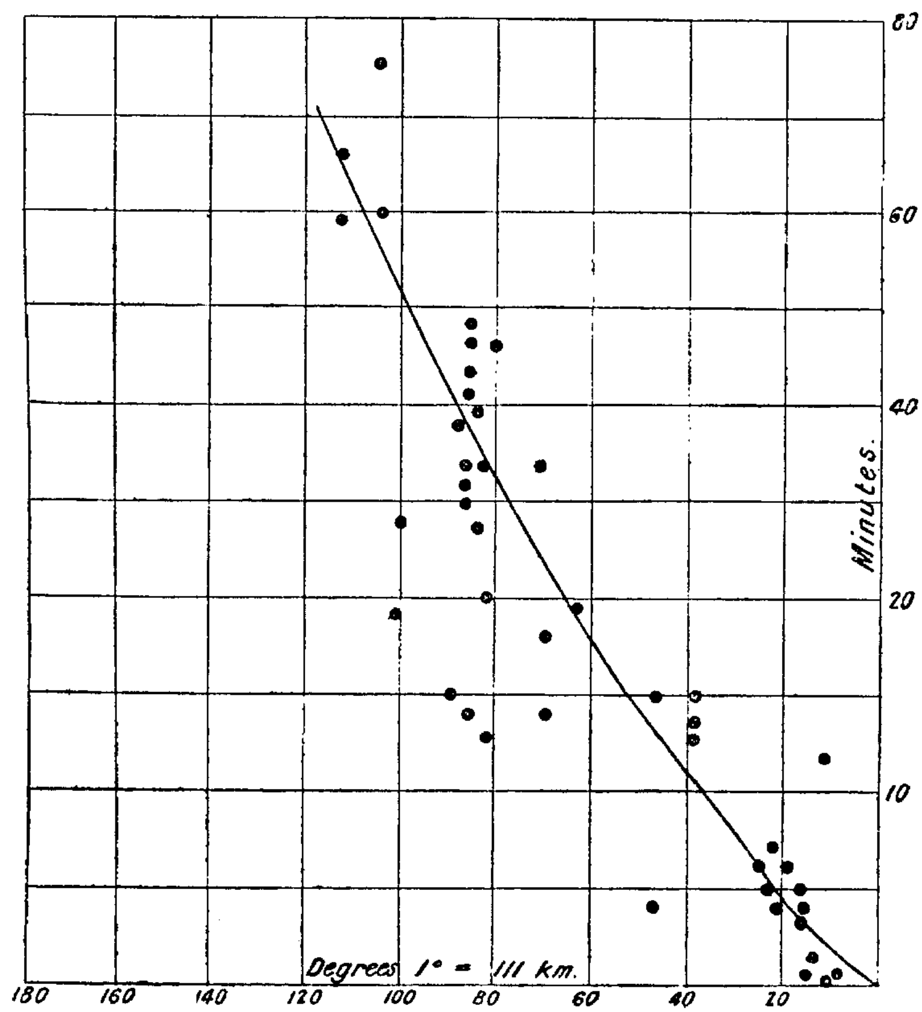
| Epicentre | Date | Nicolaiew | Rome | Siena | Charkow | Rocca di Papa | Padua | Ischia | Catania | Strassburg | Shide | Carisbrooke | Potsdam | Wilhelmshaven |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S. A., Santiago | Oct. 27, 1894 | — | 48m. (104°) | 40m. (104°) | — | — | — | — | — | — | — | — | — | — |
| Mexico | Nov. 2, 1894 | 19m. (102°) | 24m. | — | — | — | — | — | — | — | — | — | — | — |
| Merida, Venezuela | Apr. 28, 1894 | — | — | — | 15m. (95°) | — | — | — | — | — | — | — | — | — |
| Japan, N.E. coast | June 15, 1895 | — | — | — | — | 27m. (86°) | 30m. (84°) | 32m. (88°) | 29m. (88°) | — | — | — | — | — |
| Japan, Tokio | Oct. 18, 1892 | 18m. (71°) | — | — | — | — | — | — | — | 14m. (86°) | — | — | — | — |
| " | Nov. 4, 1892 | 27m. (71°) | — | — | — | — | — | — | — | 25m. (86°) | — | — | — | — |
| Japan, Sakata | Oct. 31, 1896 | 14m. (71°) | — | — | — | 31m. (86°) | — | 26m. (85°) | — | 13m. (82°) | 34m. (83°) | 34m. (83°) | — | — |
| Japan, Tokio | Apr. 17, 1889 | — | — | — | — | — | — | — | — | — | — | — | 33m. (80°) | 21m. (81°) |
| Philippines | Mar. 16, 1892 | 24m. (78°) | — | — | — | — | — | — | — | — | — | — | — | — |
| Luzon | " | 21m. (78°·9) | — | — | — | — | — | — | — | — | — | — | — | — |
| Japan, Tokio | May 11, 1892 | 33m. (71°·2) | — | — | — | — | — | — | — | 27m.? | — | — | — | — |
| " | Nov. 4, 1892 | 27m. (71°) | — | — | — | — | — | — | — | 24m. | — | — | — | — |
| " | Jan. 18, 1895 | 23m. | — | — | — | — | — | — | — | — | — | — | — | — |
| Quetta | Dec. 20, 1892 | — | — | — | — | — | — | — | — | 15m. (45°·7) | — | — | — | — |
| " | Feb. 13, 1893 | — | — | — | — | — | — | — | — | 4m. (45°·7) | — | — | — | — |
| Asia Minor, Amed. | Apr. 16, 1896 | — | — | — | — | — | 7m. | — | — | — | — | — | — | — |
| Patras | Aug. 25, 1896 | — | — | — | — | — | — | — | — | — | — | — | 0m. (15°) | 0m. |
| Thebes | May 23, 1893 | 0m. | — | — | — | — | — | — | — | 0m. | — | — | — | — |
| Bucharest | Oct. 14, 1892 | — | — | — | — | — | — | — | — | 0m. (13°) | — | — | — | — |
| Naples | Jan. 25, 1893 | — | — | — | — | — | — | — | — | 0m. (9°) | — | — | — | — |
| Mount Gasgano, Italy | Aug. 10, 1893 | — | — | — | — | — | — | — | — | 0m. (9°) | — | — | — | — |
| Cyprus | June 29, 1896 | 12m. (12°) | 4m. (17°) | — | — | 4m. (18°) | 6m. (19°) | 3m. or 7m. (16°) | 1m. (15°) | — | — | — | — | — |
| Iceland | Aug. 26, 1896 | 7m. | 10m. (28°) | — | — | 10m. | — | 7m. (30°) | 14m. (33°) | 5m. (21°) | 2m. (16°) | — | — | — |
| Tiflis | Sept. 21, 1896 | 7m. | 4m. (20°) | — | — | 5m. (21°) | — | 5m. (23°) | 6m. (23°) | — | — | — | — | — |
| Japan | Feb. 19, 1897 | 10m. | 20m. | — | — | 26m. | — | 21m. | 15m. or 19m. | — | — | — | 11m. | — |
| Assam | June 12, 1897 | — | — | — | — | — | — | — | — | 8m.? | 10m.? | — | — | — |
| Japan | Aug. 4, 1897 | — | — | — | — | — | — | — | — | — | 30m. | — | — | — |
| N. Borneo | Sept. 20, 1897 | — | — | — | — | — | — | — | — | — | 40m. & 43m. | — | — | — |
| Hayti | Dec. 29, 1897 | — | — | — | — | — | — | — | — | — | 19m. 49s. (64°) | — | — | — |

*Apparent Duration of Preliminary Tremors.*

| Epicentre and Date | Nicolaiew | Rome | Siena | Charkow | Rocca di Papa | Padua | Ischia | Catania | Strassburg | Shide | Carisbrooke | Potsdam | Wilhelmshaven | Dorpat |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Persian Gulf, Kishim, Jan. 10, 1897 | 7m. | — | — | — | — | 13m. | 15m.? | 13m. | — | — | — | — | — | 5m. |
| Umbria, Jan. 19, 1897 | — | 35s. | — | — | — | — | — | — | — | — | — | — | — | — |
| Sicily, Calabria, Feb. 11–12, 1897 | — | 5m. | — | — | — | — | 2m. | — | — | — | — | — | — | — |
| Romana, Apr. 3, 1897 | — | 10s. (35 km.) | — | — | — | — | — | — | — | — | — | — | — | — |
| Romana, Apr. 3, 1897 | — | 10s. (35 km.) | — | — | — | — | — | — | — | — | — | — | — | — |

These time intervals and their corresponding distances are shown graphically in the following figure, in which the free curve indicates the general result towards which the observations point :—

FIG. 4.




Intervals by which Preliminary Tremors have outraced Long-period Waves.

Inasmuch as these records have been obtained from different types of instruments which have had different degrees of sensibility, it is clear that they cannot be regarded as individually comparable; but when plotted on squared paper and taken in groups, it is evident that these time intervals increase with the length or depth of the wave-path over or at which a disturbance has travelled. In a few instances, as for example in the case of disturbances originating near Japan, Borneo, and Hayti, which have been recorded by the same or similar instruments in the Isle of Wight and Toronto, such observations are comparable, and they take up expected positions on the average curve of duration drawn through the groups of observations which are not so strictly comparable.

The expectation from this is that this curve will, by future observations, be found to be approximately correct.

An inspection of the same shows that the preliminary tremors up to distances of 12° or 15° only outrace the succeeding waves by intervals seldom reaching a minute. On paths between 20° and 85° the intervals are proportional to the length of the arc, but beyond this range it seems that they may increase at a somewhat higher rate.

Between Europe and Japan, or a distance of 85°, observations have shown that the interval by which the larger waves are outraced varies from 30 to 34 minutes. If we take 32 minutes as an average, then it is easy to compare what should be expected, and what has been observed on ranges lying between 20° and about 100°. This is done in the following table :—

| | |
|---|---|
| Japan to Shide, 85° | Observation, 32 minutes. |
| Borneo to Shide, 112°, 42 min. expected. | „ 40 to 43 „ |
| Hayti to Shide, 62°, 23 „ „ | „ 20 „ |
| Hayti to Toronto, 20°, 7 „ „ | „ about 4 „ |

Although these observations indicate a working rule, enabling us to determine the distance of an origin from an observing station which, with a knowledge of the surface configuration of our globe and localities where seismic activity is frequent often, are the means of locating an epicentre, the last of the series suggests that the duration of the preliminary tremors are more directly connected with the depth of a wave-path rather than its length, as represented by the arc of a great circle.

Trial, however, shows that the duration of preliminary tremors is not proportional to the length of the chord along which it may be supposed the movements travelled, or to its maximum or average depth.

The table on p. 221, which is derived from fig. 4, shows that the duration of preliminary tremors in minutes is, for the given ranges, nearly equal to the square root of the average depth of the chord expressed in kilometres.

*On the Period of Earthquake Waves at Great Distances from their Origin.*

All that we know about the period of earthquake waves after they have travelled great distances is derived from the open diagrams of the Italian workers, a few records obtained in the Isle of Wight, and a single but exceedingly valuable record obtained by Dr. F. Omori when in Potsdam. The Italian and Isle of Wight records were obtained from simple or horizontal pendulums writing on smoked paper. The Potsdam record, which refers to an earthquake originating in Japan on February 19, 1897, is photographic, and shows the movements of a pair of von Rebeur pendulums. It has yet to be described.

In the following few examples of records referring to period the following abbreviations are used :—

Pt. = Preliminary tremors, the periods of which are expressed in seconds.
Lw. = Large waves, ,, ,, ,, ,,
P. = Simple pendulum, the length of which is given in metres. These pendulums have multiplying indices.
H.P. = Horizontal pendulums.
G.L. = Geodynamic level (see p. 263, also 'B.A. Report,' 1896, p. 227).

The first name refers to the place at which a given earthquake originated.

| | | | |
|---|---|---|---|
| 1895. | Jan. 18. | Japan. | At Rome P. 16m. gave for Lw. 16·4s. |
| ,, | July 8. | Caspian Sea. | ,, Ischia G.L. ,, ,, ,, 22s. |
| ,, | Aug. 9. | E. Italy. | ,, Rome P. 16m. ,, ,, ,, 8·8s. and Pt. ·46s. |
| | | | ,, Rocca di Papa P. 7m. gave for Lw. 7s. |
| 1896. | June 15. | Japan. | ,, Padua P. gave for Lw. 40s. |
| | | | ,, Ischia H.P. (with a natural period of 11s) gave Pt. 6s. to 12s., and Lw. 20s. to 50s. |
| | | | ,, Catania gave Pt. 3s., Lw. 15·5s. |
| | | | ,, Rome P. 8m. gave 21s., P. 16m. 14s. to 20s. |
| 1896. | June 29. | Cyprus. | ,, Ischia H.P. gave Pts. 4s., Lw. 10s. |
| | | | ,, Rocca di Papa P. gave Pt. 4s., Lw. 6s. |
| ,, | Aug. 26. | Iceland. | ,, Rome P. 16m. gave Lw. 10s., P. 8m. gave Lw. 10s. |
| | | | ,, Rocca di Papa P. 15m. gave Lw. 14s., P. 7m. gave Lw. 14s. |
| | | | ,, Ischia H.P. gave Lw. 18s. |
| ,, | Aug. 31. | Japan. | ,, Ischia H.P. gave Lw. 60s. down to 13s. |
| | | | ,, Rocca di Papa H.P. Lw. 30s. to 14s., P. m gave Lw. 14s., P. 15m. 30s. and 14s. |
| | | | ,, Rome P. 16m. 8s. to 13s. |
| | | | ,, Catania P. Lw. 48s. to 72s., Pt. 14s. to 28s. |
| ,, | Sept. 6. | Iceland. | ,, Rome P. 16m. gave 11·5s. |
| | | | ,, Catania Lw. 15s. to 18s.; also 8s. to 16s. |
| | | | ,, Rocca di Papa P. 15m. gave 14s., H.P. gave 16s., P. 7m. gave 16s. |
| | | | ,, Ischia H.P. 2 2s. to 17s. |
| ,, | Sept. 22. | Tiflis. | ,, Ischia H.P. gave Pt. 2·5s., Lw. 19s. |
| | | | ,, Rocca di Papa H.P. gave about 17s. |
| ,, | Nov. 1. | Tashkent. | ,, Rocca di Papa H.P. gave 18s. |
| | | | ,, Ischia H.P. 6s. to 25s. |
| 1897. | Jan. 10. | Persian Gulf. | ,, Padua P. gave 35s. to 16s., Ischia H.P. gave 25s. to 12s. |
| | | | ,, Catania P. 25m. gave 6s. to 18s. |
| ,, | June 12. | N.E. India. | ,, Shide H.P. gave 15s. |

When reading the above records it must be remembered that they refer to the shortest and longest periods which were observed, or to waves with the smallest and largest amplitudes. Near to an origin, after a shock, a disturbance dies out with an increasing period, but at a great distance from an origin the maximum movements which probably correspond to a shock or shocks are those which have the longest period.

Also the fact must not be overlooked that the records refer to seismograms obtained from different instruments, located at different stations, and that it is not certain that comparisons are made between similar phases of motion. The following table is therefore tentative, and when we are in possession of records more strictly comparable it may be subject to considerable alteration :—

| Distance from Origin in Degrees | Period in Seconds | |
|---|---|---|
| | Preliminary Tremors | Large Waves |
| 0 to 3 | ·05 to ·2 | 1 to 4 |
| 8 to 10 | 4 ? | 10 |
| 23 to 28 | 2·2 | 19 |
| 35 to 40 | 6 ? | 35 |
| 85 | 3 to 8 | 20 to 60 |

All that this table tells us is that both preliminary tremors and large waves exhibit a marked increase in period as they travel, and, whatever the period of a given wave may be in the vicinity of its origin when it has travelled a distance represented by a quarter of the circumference of the earth, its period has increased twentyfold.

## VI. *On Certain Disturbances in the Records of Magnetometers and the Occurrence of Earthquakes. By* JOHN MILNE.

Although we are aware that the records from certain magnetic observatories rarely, and then only slightly, show that the magnetographs have been disturbed at or about the time of large earthquakes, it is certain that at other observatories these movements of the ground are accompanied and possibly preceded by perturbations as shown upon magnetograms of a very marked character. In some instances these disturbances have evidently resulted from the mechanical shaking to which the magnetic needles have been subjected, but there are other cases where such an explanation is not so clear.

To determine how far these movements may be attributed to mechanical action, whether there is any reason to suppose that certain of them may be the result of magnetic influences, to explain the observation that what are apparently similar earthquakes with like origins are accompanied by different results at the same observatory, and generally with the object of throwing additional light upon a class of phenomena which at present are not well understood, I have collected the materials contained in the following notes.

In addition to sending the list of 'Earthquakes recorded at Shide, 1897-98' (see p. 191), to various earthquake observatories, the same was forwarded to magnetic observatories at the following places : Kew, Stonyhurst, Greenwich, Falmouth, Potsdam, and Bombay. Accompanying the list there was a request that the same might be returned with notes respecting any magnetometer perturbations which might have been noted at about the times of the earthquakes which were more pronounced.

Some time later I drew up a second list of earthquakes which had been recorded in Italy, Germany, and England, the greater number of which had originated at great distances from these countries, and appended to the same a request similar to that attached to the Shide list. On April 5 this was forwarded to magnetic observatories at the following places :—

Pawlowsk (Odessa), Kasan and Tiflis (Russia), Irkutsk (Siberia), Prague, Vienna, and Pola (Austria), Ó-Gyalla (Hungary), Utrecht (Holland), Nice and Perpignan (France), Copenhagen (Denmark), Madrid

(Spain), Coimbra (Portugal), Kew, Greenwich, and Stonyhurst (England), Zi-ka-wei and Hong Kong (China), Manila (Philippine Islands), Batavia (Java), Mauritius, Melbourne (Australia), Loanda (West Africa), Havana (Cuba), Toronto (Canada), Washington (United States), Bombay (India), Tokio (Japan).

*Earthquakes recorded in Germany, Italy, and England, many of which originated at great distances from these Countries.*

The time employed is Greenwich Mean Time.

| No. | Date | Hour | Origin | Magnetometer Disturbances: Kew | Utrecht | Copenhagen | Vienna | Pola | Bombay | Potsdam | Wilhelmshaven | Pawlowsk | Mauritius | Zikawei | Greenwich |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | H. M. | | | | | | | | | | | | | |
| | 1889. | | | | | | | | | | | | | | |
| 1 | Apr. 18 | 5 21 a | Japan . | | | | | | | | | | — | — | — |
| 2 | July 11 | 10 22 p | Quetta . | | — | | | | — | | | | — | | — |
| 3 | „ 28 | 3 30 p | Japan . | | | | | | | | | | — | | |
| 4 | „ „ | 6 0 p | „ . | | | | | | | | | | | — | — |
| 5 | Aug. 25 | 7 37 p | Greece . . | — | | | | | | | | | — | | — |
| | 1891. | | | | | | | | | | | | | | |
| 6 | Oct. 27 | 9 38 p | Japan . . | | — | | | | | | | | — | — | — |
| | 1892. | | | | | | | | | | | | | | |
| 7 | Mar. 16 | 1 22 p | Manila . . | | | | | | | | | | — | — | — |
| 8 | „ „ | 5 22 p | „ . . | | | | | | | | | | — | | |
| 9 | Apr. 19 | 11 30 a | California . | | — | | | | | | | | | | |
| 10 | May 12 | 5 43 a | Japan . . | — | — | | | — | | | | | | | — |
| 11 | Oct. 19 | 4 21 a | „ . . | — | | | | | | | | | — | — | — |
| 12 | Nov. 4 | 5 24 p | „ . . | — | | | | | | | | | — | | — |
| 13 | „ 27 | 5 57 p | California . | | | | | | | | | | — | | — |
| 14 | Dec. 9 | 1 19 a | Japan . . | | | | | | | | | | — | | — |
| 15 | „ 20 | 0 34 a | Quetta . . | | | | | | | | | | | | — |
| | 1893. | | | | | | | | | | | | | | |
| 16 | Jan. 28 | 11 46 p | Italy . . | — | — | | | | | | | | — | | — |
| 17 | „ 31 | 4 19 a | Zante . . | | | | | | | | | | | | — |
| 18 | Feb. 1 | 0 39 a | „ . . | | | | | | | | | | | | |
| 19 | „ 6 | 5 7 p | Japan . . | | | | | | | | | | — | — | — |
| 20 | „ „ | 7 4 p | „ . . | | | | | | | | | | | | — |
| 21 | „ 9 | 6 13 p | Turkey . . | — | | | | — | — | | | | — | | — |
| 22 | „ „ | 9 40 p | Japan . . | | | | | | — | | | | — | | — |
| 23 | „ „ | 11 0 p | „ . . | | | | | | | | | | | | — |
| 24 | „ 13 | 5 0 p | Quetta . . | | | | | | | | | | — | — | |
| 25 | „ 16 | 5 17 a | Japan . . | | | | | | | | | | — | — | — |
| 26 | „ „ | 0 4 p | „ . . | | — | | | | | | | | | | — |
| 27 | „ 21 | 7 13 a | „ . . | | | | | | | | | | | | — |
| 28 | „ „ | 2 18 p | „ . . | | | | | | | | | | | | — |
| 29 | „ 22 | 11 16 p | „ . . | | | | | | | | | | | | — |
| 30 | Mar. 2 | 11 6 p | Turkey . . | — | — | — | | | | | | | — | | — |
| 31 | „ 14 | 6 20 a | Italy . . | | | | | | | | | | — | | — |
| 32 | „ 20 | 5 10 p | Zante . . | | | | | | | | | | — | | — |
| 33 | „ 23 | 8 43 p | Japan . . | | — | | | | | | | | — | | — |
| 34 | Apr. 8 | 1 51 p | S.W. Germany . | — | — | — | — | | | | | | — | | — |
| 35 | „ 17 | 5 48 a | Zante . . | | | | | | | | | | — | | — |
| 36 | „ 23 | 1 32 p | Italy . . | | — | | | | | | | | | | |
| 37 | „ 29 | 6 2 p | „ . . | | | | | | | | | | — | | |

EARTHQUAKES RECORDED IN GERMANY, ITALY, AND ENGLAND—*continued.*

| No. | Date | Hour | Origin | Magnetometer Disturbances | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Kew | Utrecht | Copenhagen | Vienna | Pola | Bombay | Potsdam | Wilhelmshaven | Pawlowsk | Mauritius | Zikawei | Greenwich |
| 38 | May 2 | 9 58 a | „ . . | | | | | | | | | | | | — |
| 39 | „ 18 | 2 39 p | „ . . | | | | | | | | | | — | | — |
| 40 | „ 19 | 1 3 a | „ . . | | — | | | | | | | | | | — |
| 41 | „ 23 | 8 38 p | Greece . . | — | — | | | | | | | | — | | — |
| 42 | June 3 | 4 25 p | Unknown . | — | | | — | | | | | | — | | |
| 43 | „ 7 | 10 10 p | Italy . . | | | | | | | | | | | | — |
| 44 | „ 11 | 9 9 p | „ . . | | | | | | | | | | — | — | — |
| 45 | „ 13 | 11 5 a | „ . . | | | | | | | | | | | | |
| 46 | „ 14 | 6 47 a | Greece . . | | | | | | | | | | | | |
| 47 | July 3 | 10 5 a | „ . . | | | | | | | | | | | | — |
| 48 | „ 5 | 11 24 a | Italy . . | | | | | | | | | | | | |
| 49 | „ 10 | 0 14 p | „ . . | | | | | | | | | | | | |
| 50 | Aug. 2 | 1 43 a | „ . . | | — | | | | | | | | | | |
| 51 | „ 4 | 0 52 a | „ . . | | | | | | | | | | | | — |
| 52 | „ 6 | 7 42 p | „ . . | | | | — | | | | | | — | — | — |
| 53 | „ 10 | 9 9 p | „ . . | | | | | | | | | | | | — |
| 54 | „ 14 | 7 48 p | „ . . | | | | | — | | | | | | | — |
| | 1894. | | | | | | | | | | | | | | |
| 55 | Mar. 22 | 10 37 a | Japan . . | — | — | | | — | | | | | — | — | — |
| 56 | Apr. 20 | 5 42 p | Greece . . | | | | | | | | | | | | — |
| 57 | „ 27 | 7 55 p | „ . . | | — | — | | | | | | | | | — |
| 58 | „ 29 | 3 25 a | Venezuela . | | | | | | | | | | — | | — |
| 59 | June 20 | 5 45 a | Japan . . | | | | | | | | | | — | — | — |
| 60 | July 10 | 10 30 a | Constantinople . | — | — | — | | | | | | | | | — |
| 61 | „ 12 | 2 17 p | „ . | | | — | | — | | | | | | | |
| 62 | Oct. 7 | 11 40 a | Japan . . | | | | | | | | | | — | — | — |
| 63 | „ 22 | 9 0 a | „ . . | — | — | | | | | | | | | | — |
| 64 | „ 27 | 9 8 p | Argentina . | — | — | | | | | | | | — | — | — |
| | 1895. | | | | | | | | | | | | | | |
| 65 | Jan. 18 | 2 37 p | Japan . . | | | | | — | | | | | — | — | — |
| 66 | July 8 | 10 43 p | Caspian Sea | | — | — | | — | | — | — | — | — | — | — |
| 67 | Aug. 9 | 5 38 p | E. Italy . | | | | | — | | | | | — | — | — |
| 68 | Nov. 13 | 9 31 p | W. Asia Minor . . | | | | | | | | | | — | | — |
| | 1896. | | | | | | | | | | | | | | |
| 69 | June 15 | 11 46 a | Japan . . | — | — | | — | | | | | | — | | — |
| 70 | „ 29 | 9 2 p | Cyprus . . | | | | | | | | | | — | | — |
| 71 | Aug. 26 | 11 22 p | Iceland . . | | — | | | | | — | — | | | | — |
| 72 | „ 31 | 8 23 a | Japan . . | | | | | | — | | — | | — | | — |
| 73 | Sept. 6 | 0 2 a | Iceland . . | | — | | | | — | — | | | | | — |
| 74 | „ 14 | 10 30 a | N.W. Asia Minor . | | | | | | | | | | | | — |
| 75 | „ 22 | 4 53 a | Tiflis . . | | | | | | | — | — | | — | | — |
| 76 | Nov. 1 | 5 18 a | Tashkent . | | — | — | | | | — | — | | | | — |
| | 1897. | | | | | | | | | | | | | | |
| | Jan. 10 | 9 18 p | Persian Gulf . | | | | | — | | | | | — | | |
| | June 12 | 11 29 a | N.E. India . | — | — | — | | | — | | — | — | — | | |
| | Aug. 5 | 0 22 a | Japan . . | | — | | | | | | | | | | |
| | Sept. 20 | 7 24 p | E. Borneo . | | | | | | | | | | — | | |
| | „ 21 | 5 28 a | „ . | | — | | | — | — | | | | — | | |
| | Dec. 28 | 8 54 p | W. Indies . | | | | | | | | | | | | |
| | „ 29 | 11 40 a | „ . | | | | | | | | | | — | | |

The chief feature in this list is that with one exception it refers to earthquakes of which we know the origin. The exception is No. 42, and it is here included because it refers to an earthquake which probably disturbed the whole of the globe, and had a duration greater than any yet recorded. In Japan I recorded it as having a duration of 5 hrs. 24 mins. In Strassburg it continued 11 or 12 hours.

In the columns for magnetometer disturbances, especially for Kew and Mauritius, it must not be inferred that the marks necessarily indicate anything more than that slight magnetic perturbations have occurred at about the times specified. The Potsdam, Wilhelmshaven, and Pawlowsk records date from 1895.

Further information has been obtained from the earthquake catalogues published from time to time by Professor Pietro Tacchini in the 'Bollettino della Società Sismologica Italiana.'

These records date only from 1895, and refer to Utrecht, Potsdam, Wilhelmshaven, and Pawlowsk.

What has been gathered from these lists, together with that from replies to circulars, more of which may yet be expected, is tabulated in a uniform manner in the following lists :—

0, as, for example, 'Potsdam = 0,' means that the magnetographs at Potsdam were not disturbed.

D means Declinometer or the unifilar record.

H means Horizontal Force record.

V means the Vertical Force, or Lloyd's balance record.

The times are given in hours and minutes G.M.T.

### *Replies relating to the List on p.* 191.
### (*Earthquakes recorded at Shide, Isle of Wight*, 1897–98.)

#### 1. *Records from the Kew Observatory, Richmond, Surrey. Superintendent,* Dr. Charles Chree, *F.R.S.*

Dr. Charles Chree, F.R.S., superintendent of the above observatory, tells me that he and Mr. Baker have looked at the curves, chiefly for horizontal force, at the times of the *large* movements in the Shide list, and he points out that near these times—as near any other set of arbitrary times—there are movements of the ordinary magnetic small wave type. Such movements go on for hours, if not for days; and by some the view is held that they are always, or nearly always, existent, and might be seen if we had only delicate enough instruments and an open time scale. When earth movements have affected the trace there is a 'burr,' but such a 'burr' might be equally well caused by an assistant entering the room with keys or a knife in his pocket. In only one case—No. 104, June 3—was there evidence of a movement not due to natural magnetic causes, excepting one on October 20, No. 141, which might more naturally be assigned to human creation. The June 3 movement would pass for an earthquake, but it took place at an hour when there are frequent movements in the building, as absolute meteorological observations are taken then. Traces free from small movements, excepting the vertical force, are rare. On a moderately disturbed day the movements are in dozens, or rather hundreds. In the following list the numbers refer to those on the Shide list, and if these are followed by $=0$ this means that at the corresponding dates the magnetometers were not disturbed : $98=0$. 104. At

10 A.M. a slight movement, apparently not magnetic. 116=0. 119=0. 131=0. 132=0. 133 probably = 0. 134=0. 140=0. 141. At 2.58 P.M. movements probably due to an assistant. 145=0. 157=0. 163. A slight movement, about 2.50 P.M., of a doubtful kind.

*Records from the Royal Observatory, Greenwich.*

Through the kindness of the Astronomer Royal, the following note relating to the Shide register, p. 191, were drawn up by Mr. Nash :—

| Shide No. | Movements noted at Greenwich. |
|---|---|
| 98* | Small movement in H and D at 23h. 30m. |
| 99 | „ „ „ about 12h. 20m. |
| 100 | „ „ „ at 13h. 15m. |
| 101 | Very small movements in H and D. |
| 102 | „ „ „ D. |
| 103 | Small movements in H and D at 4h. 45m. |
| 104* | Small wave in H and D at 9h. 50m. |
| 105 | Very small movement in D at 11h. 45m. |
| 106 | Small „ in D at 19h. 55m. |
| 107* | „ wave in H and D at 7h. 30m. |
| 108 | „ movement in H at 10h. 55m. |
| 110 | „ wave in H at 20h. 15m. |
| 111 | „ movement in H at 14h. 15m. |
| 115 | Very small fluctuations in H and D. |
| 116* | „ „ movement in D at 15h. 40m. |
| 118* | „ „ „ in D and H, 6h. 10m. to 6h. 45m. |
| 120 | „ „ „ in H and D at 21h. 45m. |
| 122 | „ „ wave in D. |
| 123 | Small decrease in H and D at 15h. 10m. |
| 125* | „ wave in H and D at 1h. 20m. |
| 130 | Very small movement in H about 19h. 28m. |
| 131 | Small movement in H. |
| 132* | „ wave in H and D at 23h. 50m. |
| 134 | „ movement in H and D at 13h. 40m. ± |
| 136 | Wave in H and D at 0h. 15m. |
| 137* | Small movement in H at 14h. 40m. |
| 142 | „ „ in H and D 3h. 30m. |
| 143 | „ wave in D. |
| 144 | „ movement in H at 9h. 48m. |
| 147* | Active movements in H and D, commencing a 4h. |
| 155 | Small „ in H and D. |
| 156 | Very small „ in D. |
| 160 | Small „ in H, again in D & H, 17h. 40m. to 17h. 45m. |

We have here 33 instances where it is possible that a connection may exist between earthquake movements and the movements of magnetic needles. In the cases marked with an asterisk the movements of the needles preceded those of the ground.

*Replies relating to the List on p. 227.*

*Magnetometer Movements noted at the Kew Observatory, Richmond, Surrey, England. Superintendent,* Dr. CHARLES CHREE, *F.R.S.*

| No. | No. on List p. 227 | Month | Day | Time of Earthquake | Magnetometer Disturbances |
|---|---|---|---|---|---|
| | | | | | **1889.** |
| 1 | 1 | IV. | 18 | H. M. 5 21 A.M. | D and H no trace of earthquake. The previous two days were very quiet except for some *small* movements on the 17th—1 to 3 P.M. and 5 to 7 P.M. |
| 2 | 5 | VIII. | 25 | 7 37 P.M. | On D some very small, apparently ordinary, magnetic movements about 7.37. On H small movements—all say on 25th—the largest between 4 and 6 P.M., but no trace of earthquake. The 24th distinctly quiet, but for slow moderate movements of D about 10 P.M. |
| | | | | | **1892.** |
| 3 | 10 | V. | 12 | 5 43 A.M. | D trifling movements, but they look magnetic. H shows no trace of earthquake. On the 11th very quiet. H shows lots of small movements, the largest (not big) shortly before midnight. |
| 4 | 11 | X. | 19 | 4 21 A.M. | D and H no earthquake movement. Noon 17th and 10 P.M. on 19th many varied movements. The fastest large change of H on the 18th about 5 and 8 P.M. Sharp change of D on 18th between 5 and 5.30 P.M. |
| 5 | 12 | XI | 4 | 5 24 P.M. | D many small movements, but no certain earthquake. No trace of earthquake on H. Many small disturbances on the 4th up to 4.30 P.M.; pretty sudden commencement on the 4th about 2.29 A.M. |
| 6 | 14 | XII. | 9 | 1 19 A.M. | D and H no trace of earthquake. On the 8th many smallish movements from 8 A.M. to 11 P.M. Largest on D about noon. |
| | | | | | **1893.** |
| 7 | 21 | II. | 9 | 6 13 P.M. | Certain small movements might be earthquake effect, but there are several not dissimilar at no great time interval. The 9th, but for many small vibratory movements, was quiet. The 8th was generally quiet. A small slow movement of H at 10.40 to 11.20 P.M. |
| 8 | 30 | III. | 2 | 11 6 P.M. | No trace of earthquake on D. Some movements but apparently magnetic, on H. The 2nd was generally quiet. On the 1st two well-marked movements last 7.20 to 8.30 P.M. |
| 9 | 31 | III. | 14 | 6 20 A.M. | No trace of earthquake on D and H. 13th and 14th, on the whole, quiet; on 13th some slow waves on H between 1.45 and 8 P.M., also on D about 12.30 to 2 P.M. and about 6 P.M. |

MAGNETOMETER MOVEMENTS—*continued.*

| No. | No. on List p. 227 | Month | Day | Time of Earthquake | Magnetometer Disturbances |
|---|---|---|---|---|---|
| | | | | H. M. | |
| 10 | 34 | IV. | 8 | 1 51 P.M. | No trace of earthquake of E or H. D a little irregular, but nothing special, at 1 51. The 8th and 7th generally quiet, but many small vibrations on D on 7th and early on the 8th. |
| 11 | 42 | VI. | 3 | 4 25 P.M. | Some slight movements, apparently magnetic. The 3rd and 2nd generally quiet. A few *small* movements on D on the 2nd and early on the 3rd. |
| 12 | 45 | VI. | 13 | 11 5 A.M. | No trace of earthquake on H or D. On the 12th H shows a slight hump from 0 to 1 A.M., otherwise very quiet; D shows a lot of very small movements, a noticeably sharp one about 6.15 A.M., and a hump on curve from midnight to 1 A.M. |

*Magnetometer Movements noted at the Royal Observatory, Greenwich, from* 1889 *to* 1896. *Drawn up by* Mr. P. H. COWELL.

[For a more detailed description see the Greenwich volumes.]

| No. | No. on List p. 227 | Month | Day | Time of Earthquake | Beginning of Magnetometer Disturbances |
|---|---|---|---|---|---|
| | | | **1889.** | | |
| | | | | H. M. | |
| 1 | 1 | IV. | 18 | 5 21 A.M. | Very small, from 17d. 9h. A.M. to 6h. P.M. |
| 2 | 2 | VII. | 11 | 10 22 P.M. | 2h. P.M. |
| 3 | 5 | VIII. | 25 | 7 37 P.M. | From noon. |
| | | | **1891.** | | |
| 4 | 6 | X. | 27 | 9 38 P.M. | „ 4h. 45m. P.M. |
| | | | **1892.** | | |
| 5 | 7 | III. | 16 | 1 22 P.M. | From 15d. 8h. P.M. to 16d. 3h. A.M. |
| 6 | 10 | IV. | 12 | 5 43 A.M. | Small disturbance from 11d. 11h. 30m. P.M. |
| 7 | 11 | X. | 19 | 4 21 A.M. | Storm from 17d. noon. |
| 8 | 12 | XI. | 4 | 5 24 P.M. | „ „ 4d. 2h. A.M. |
| 9 | 13 | „ | 27 | 5 57 P.M. | From 26d. 2h. 30m. A.M. to 5h. A.M. |
| 10 | 14 | XII. | 9 | 1 19 A.M. | Disturbance from 8d. 2h. A.M. to midnight. |
| 11 | 15 | „ | 20 | 0 34 A.M. | From 19d. 10h. 30m. P.M. |
| | | | **1893.** | | |
| 12 | 16 | I. | 28 | 11 46 P.M. | From 0h. 30m. A.M. |
| 13 | 17 | „ | 31 | 4 19 A.M. | „ 1h. 30m. A.M. |
| 14 | 19 | II. | 6 | 5 7 P.M. | } Storm from 4d. noon to 6d. noon. Subsequently a large disturbance. |
| 15 | 20 | „ | „ | 7 4 P.M. | |
| 16 | 21 | „ | 9 | 6 13 P.M. | From 9d. 6h. P.M. |
| 17 | 22 | „ | „ | 9 40 P.M. | |
| 18 | 23 | „ | „ | 11 0 P.M. | |
| 19 | 25 | „ | 16 | 5 17 A.M. | } Considerable disturbance from 15d. 1h. P.M. |
| 20 | 26 | „ | „ | 0 4 P.M. | |

MAGNETOMETER MOVEMENTS—*continued.*

| No. | No. on List p. 227 | Month | Day | Time of Earthquake | Beginning of Magnetometer Disturbances |
|---|---|---|---|---|---|
| | | | | H. M. | |
| 21 | 27 | ,, | 21 | 7 13 A.M. | Disturbance from 20d. 5h. P.M. to 10h. P.M. |
| 22 | 28 | ,, | ,, | 2 18 P.M. | ,, ,, 21d. noon. |
| 23 | 29 | ,, | 22 | 11 16 P.M. | Slight ,, ,, 22d. noon — principally at 8 P.M. |
| 24 | 30 | III. | 2 | 11 6 P.M. | From 10h. 30m. P.M. |
| 25 | 31 | ,, | 14 | 6 20 A.M. | ,, 3h. A.M. |
| 26 | 33 | ,, | 23 | 8 43 P.M. | Very small disturbance from 6h. P.M. |
| 27 | 34 | IV. | 8 | 1 51 P.M. | ,, ,, ,, ,, 1h. to 10h. A.M. |
| 28 | 35 | ,, | 17 | 5 48 A.M. | Disturbances from 16d. 3h. P.M. Small disturbance 17d. 4h. A.M. |
| 29 | 38 | V. | 2 | 9 58 A.M. | A small, sharp disturbance 1d. 10h. P.M. |
| 30 | 39 | ,, | 18 | 2 39 P.M. | Disturbance at noon. |
| 31 | 40 | ,, | 19 | 13 A.M. | Small at 18d. 8h. P.M., and a smaller at 19d. 1h. A.M. |
| 32 | 41 | ,, | 23 | 8 38 P.M. | At 6h. P.M. |
| 33 | 42 | VI. | 3 | 4 25 P.M. | Register interrupted for Visitation Day. |
| 34 | 43 | ,, | 7 | 10 10 P.M. | A great disturbance 6d. 9h. P.M. Fluctuations subsequently. |
| 35 | 44 | ,, | 11 | 9 9 P.M. | Disturbance from 10d. 7h. P.M. |
| 36 | 47 | VII. | 3 | 10 5 A.M. | Very small disturbance since 2d. 11h. A.M. |
| 37 | 51 | VIII. | 4 | 0 52 A.M. | From 3d. 7h. P.M. |
| 38 | 52 | ,, | 6 | 7 42 P.M. | Storm beginning 6d. 4h. A.M. |
| 39 | 53 | ,, | 10 | 9 9 P.M. | From 3h. P.M. |
| 40 | 54 | ,, | 14 | 7 48 P.M. | Very small disturbance 5h. 30m. P.M. |
| | | | | **1894.** | |
| 41 | 55 | III. | 22 | 10 37 A.M. | Storm commences 21d. noon. |
| 42 | 56 | IV. | 20 | 5 42 P.M. | Fluctuations from 5h. A.M. |
| 43 | 57 | ,, | 27 | 7 55 P.M. | Slight irregularity at 3h. A.M. |
| 44 | 58 | ,, | 29 | 3 25 A.M. | From 1h. A.M. |
| 45 | 59 | VI. | 20 | 5 45 A.M. | Moderate disturbance for some time past. Wave at 4h. A.M. |
| 46 | 60 | VII. | 10 | 10 30 A.M. | From 9d. 8h. P.M. |
| 47 | 62 | X. | 7 | 11 40 A.M. | ,, 6h. A.M. |
| 48 | 63 | ,, | 22 | 9 0 A.M. | ,, 0h. A.M. |
| 49 | 64 | ,, | 27 | 9 8 P.M. | ,, 5h. P.M. |
| | | | | **1895.** | |
| 50 | 65 | I. | 18 | 2 37 P.M. | From 17d. noon. |
| 51 | 66 | VII. | 8 | 10 43 P.M. | ,, 6h. A.M. and 1h. P.M. |
| 52 | 67 | VIII. | 9 | 5 38 P.M. | ,, 8h. A.M. |
| 53 | 68 | XI. | 13 | 9 31 P.M. | ,, 7h. P.M. |
| | | | | **1896.** | |
| 54 | 69 | VI. | 15 | 11 46 A.M. | From 14d. 2h. A.M. to 15d. 3h. A.M. Sharp waves 14d. 3h. 30m. to 6h. P.M. |
| 55 | 70 | ,, | 29 | 9 2 P.M. | From 3h. P.M. to midnight. Waves 6h. 30m. to 9h. 30m. P.M. |
| 56 | 71 | VIII. | 26 | 11 22 P.M. | Almost continuous from 23d. 2h. P.M. to 25d. 9h. P.M. |
| 57 | 72 | ,, | 31 | 8 23 A.M. | From 29d. noon to 30d. noon. Marked at 29d. 4h. P.M. |
| 58 | 73 | IX. | 6 | 0 2 A.M. | From 4d. noon to 5d. 10h. P.M. Marked on 5d. 8h. 30m. to 10h. A.M. |

It will be observed that these records, unlike those in the next register for Utrecht, do not refer to 'burr'-like markings produced at the time of earthquakes, but to magnetic movements which have had a considerable duration, and which commenced some hours before the occurrence of the earthquakes to which they are in juxtaposition.

For fourteen earthquakes it will be noticed that there is no corresponding magnetic disturbance, but, singularly enough, at least ten of these earthquakes were small, originating, for example, in Italy, the mechanical movements accompanying which were not recordable even at so short a distance as England. Apparently, therefore, the greater number of perturbations recorded at Greenwich have only preceded very large earthquakes representing internal adjustments of the earth's crust. Something analogous to this will be found in the Zikawei register, p. 245.

*Magnetometer Disturbances recorded at the Royal Meteorological Institute of the Netherlands, Utrecht. Director*, Dr. M. SNELLEN.

| No. | No. on List p. 227 | Month | Day | Time of Earthquake | Magnetometer Disturbances |
|---|---|---|---|---|---|
| | | | | **1889.** | |
| | | | | H. M. | |
| 1 | 2 | VII. | 11 | 10 22 P.M. | D 10h. 42m. max. at 10h. 50m. and 11h. 1m. H 10h. 39m., with max. at 10h. 41m., 10h. 52m., 11h. 2m., and 13h. 20m. |
| | | | | **1891.** | |
| 2 | 6 | X. | 27 | 9 38 P.M. | D 9h. 0m. 8s.; 9h. 28m.; 9h. 44m. 50s.; 10h. 2m.; 10h. 8m.; 10h. 32m. H. = 0. |
| | | | | **1892.** | |
| 3 | 9 | IV. | 19 | 11 30 A.M. | D and H 11h. 33m. |
| 4 | 10 | V. | 12 | 5 43 A.M. | D and H 7h. 14m.? |
| | | | | **1893.** | |
| 5 | 16 | I. | 28 | 11 46 P.M. | D 9h. 24m.; 10h. 0m.; 11h. 2m. H 9h. 26m.; 10h. 0m. |
| 6 | 26 | II. | 16 | 0 4 P.M. | D 10h. 46m.; 11h. 34m.; 11h. 56m. H 10h. 48m.; 11h. 24m.; 12h. 4m. |
| 7 | 30 | III. | 2 | 11 6 P.M. | D 11h. 56m. H 11h. 56m. |
| 8 | 33 | | 23 | 8 43 P.M. | D 8h. 54m. H not registering |
| 9 | 34 | IV. | 8 | 1 51 P.M. | D 1h. 42m.; 1h. 56m. H 1h. 40m.; 1h. 57m. |
| 10 | 36 | | 23 | 1 32 P.M. | D 2h. 40m. H 2h. 40m. |
| 11 | 38 | V. | 2 | 9 58 A.M. | D 9h. 51m.; 9h. 58m. H 9h. 51m.; 9h. 58m. |
| 12 | 40 | — | 19 | 1 3 A.M. | D 1h. 19m. H = 0. |
| 13 | 41 | — | 23 | 8 38 P.M. | D 7h. 36m. H 8h. 20m. |
| 14 | 50 | VIII. | 2 | 1 43 A.M. | Aug. 1, D 11h. 20m. P.M.; 11h. 36m. P.M. H 11h. 36m. P.M. |
| | | | | **1894.** | |
| 15 | 55 | III. | 22 | 10 37 A.M. | D 10h. 27m.; 19h. 26m., &c. H 10h. 27m.; 11h. 21m., &c. |
| 16 | 57 | IV. | 27 | 7 55 P.M. | D 7h. 57m. H 7h. 57m. |
| 17 | 59 | | | | Not registering |
| 18 | 60 | VII. | 10 | 10 30 A.M. | D 10h. 28m. H 10h. 1m.; 10h. 32m. |
| 19 | 63 | X. | 22 | 9 0 A.M. | D 7h. 51m. H 9h. 0m. |
| 20 | 64 | — | 27 | 9 8 P.M. | D 9h. 0m.; H 9h. 8m. |

MAGNETOMETER DISTURBANCES—*continued.*

| No. | No. on List p. 227 | Month | Day | Time of Earthquake | Magnetometer Disturbances |
|---|---|---|---|---|---|
| | | | | **1895.** | |
| 21 | 66 | VII. | 8 | 10 43 P.M. | D 10h. 27m. H 10h. 26m. |
| | | | | **1896.** | |
| 22 | 69 | VI. | 15 | 11 46 A.M. | D 11h. 23m. H 11h. 26m. |
| 23 | 71 | VIII. | 26 | 11 22 P.M. | D 11h. 30m. H 11h 28m. |
| 24 | 73 | IX. | 6 | 0 2 A.M. | D 12h. 7m. H 12h. 8m. |
| 25 | 76 | XI. | 1 | 5 18 | D 5h. 31m. H 5h. 28m. |
| | | | | **1897.** | |
| 26 | 78 | VI. | 12 | 11 29 A.M. | D 11h. 18m.; 11h. 58m. H 11h. 56m. (See records from Bombay.) |
| 27 | 79 | VIII. | 5 | 0 22 A.M. | D 1h. 4m. H 0h. 59m. |
| 28 | 81 | IX. | 21 | 5 28 A.M. | D 6h. 24m. H 6h. 20m. |

To the above is added 1896, August 27, D, 10h. 54m., H, 10h. 55m., which agrees with an earthquake recorded in Europe, as, for example, at Catania at 10.52.

Out of the Utrecht records there are apparently thirteen instances, viz., Nos. 2, 5, 9, 11, 13, 14, 15, 18, 19, 20, 21, 22, and 26, in which the magnetometer perturbations have preceded the records of the seismographs by intervals varying between a few minutes and two hours.

The disturbances due to earthquakes are usually easily distinguished from ordinary magnetic disturbances and from those produced artificially, as for example by the approach and removal of masses of iron.

A copy of these disturbances was forwarded to Dr. Charles Chree, who very kindly compared the same with his own records obtained at Kew. The results were as follows :—

No. 2. Nothing special at the times specified. For several days about this date innumerable small movements occurred from time to time.

„ 5. D, a little movement about 11.25, but not at times stated. H, small movement at 10, but various similar movements both before and after.

„ 9. D, no movement at 1.42, 1.51, or 1.56. H, a small movement at 1.57.

„ 11. D, nothing at the time stated. H, nothing at 9.51 or 9.58.

„ 13. D, numerous very small tremors for some hours before and after time stated. H, nothing at 8.20.

„ 14. D, nothing at 11.20 or 11.34, or 1.34 A.M. on the 2nd. H, nothing at 11.36 P.M. on the 1st.

„ 15. D, curve disturbed this and previous day. Hundreds of movements.
H „ „ „ „ „ „ „

„ 18. D, nothing at 10.28 specially. Very small tremors 10.25 to 11.30. H, nothing at 10.1; burr on curve at 10.35.

„ 19. D, microscopic tremors about 7.48 and later. H, nothing at 9.0.

„ 20. D, considerable magnetic movement 6 to 10 P.M. Nothing special at 9 P.M. H, ditto.

„ 21. D, nothing at 10.27 or 10.43. H, nothing at 10.36 or 10.43.

„ 22. D, nothing at 11.23 or 11.46 A.M. H, lot of tiny tremors 10 A.M. to 1 P.M.; nothing special at 11.26.

„ 26. D, nothing at 11.18, 11.29, or 58 ; but at 11.38 somewhat abnormal jerk, and small movement at 11.50. H, nothing at 11.29. Movement that might well be an earthquake from 11.47 to 12.10. This is certainly not a normal magnetic movement.

Referring to the Utrecht times given for the above thirteen cases, Dr. Chree says that in some cases there was in progress either a moderately developed magnetic storm, or a series of vibrations such as are every now and then conspicuous for some time—hours or days. At such times fifty or a hundred tiny wobbles may be observed within a comparatively small time, and it would be almost impossible, in fact, not to have one within a minute or so of any specified time.

*Magnetic Disturbances recorded at Det Danske Meteorologiske Institut, Copenhagen. Director,* Dr. ADAM PAULSEN.

| No. | No. on List p. 227 | Month | Day | Time of Earthquake | Magnetic Disturbances |
|---|---|---|---|---|---|
| | | | | **1893.** | |
| | | | | H. M. | |
| 1 | 30 | III. | 2 | 11 0 P.M. | Very weak traces in H F at 11h. 3m. P.M. |
| 2 | 34 | IV. | 8 | 1 51 P.M. | Shocks in D and H at 2h. 3m. to 2h. 13m. P.M. |
| | | | | **1894.** | |
| 3 | 57 | IV. | 27 | 7 55 P.M. | Disturbances by details not received (J. M.) |
| 4 | 60 | VII. | 10 | 10 30 A.M. | Commenced 10h. 36m. A.M. At 10h. 39m. severe shock, succeeded by several shocks until 10h. 52m. A.M. |
| 5 | 61 | VII. | 12 | 2 17 P.M. | Between 2h. 15m. and 2h. 21m. P.M. |
| | | | | **1895.** | |
| 6 | 66 | VII. | 8 | 10 43 P.M. | Between 10h. 47m. P.M. and 11h. 12m P.M. Severe shocks particularly in H F. |
| | | | | **1896.** | |
| 7 | 76 | XI. | 1 | 5 18 A.M. | Traces of earthquakes between 5h. 22m and 5h. 28m. |
| | | | | **1897.** | |
| 8 | 78 | VI. | 12 | 11 29 A.M. | Severe shocks between 11h. 18m. and 11h. 57m. A.M. |

*Magnetometer Disturbances recorded at the K. K. Anstalt für Meteorologie und Erdmagnetismus, Wien, Oesterreich. Director,* Dr. J. M. PERNTER.

| No. | No. on List p. 227 | Month | Day | Time of Earthquake | Magnetometer Disturbances |
|---|---|---|---|---|---|
| | | | | **1893.** | |
| | | | | H. M. | |
| 1 | 34 | IV. | 8 | 1 51 P.M. | Apparently strong movement |
| 2 | 42 | VI. | 3 | 4 25 P.M. | Strong swinging |
| 3 | 52 | VIII. | 6 | 7 42 P.M. | Much disturbed |
| | | | | **1896.** | |
| 4 | 69 | VI. | ? | 11 46 A.M. | On the 16th much disturbed |

To the above is added the disturbance caused by the Laibach earthquake, April 14, 1895, at 10.18 A.M.

The origin of No. 1 was South-west Germany ; that of No. 2, which is one of the largest and longest earthquakes yet recorded, is unknown ; No. 52 was in Italy ; while 69 was in Japan.

The magnetographs are but rarely disturbed, and then, with one exception, only by local shocks.

*Magnetometer Disturbances recorded at the K. und K. Hydrographisches Amt, Pola.*
THE DIRECTOR.

| No. | No. on List p. 227 | Month | Day | Time of Earthquake | Magnetometer Disturbances |
|---|---|---|---|---|---|
| | | | | **1893.** | |
| | | | | H. M. | |
| 1 | 10 | II. | 1 | 0 39 A.M. | 10h. 45m. P.M. (?) |
| 2 | 21 | — | 9 | 6 13 P.M. | 3h. 35m. P.M. and 5h. 5m. P.M. |
| 3 | 54 | VIII. | 14 | 7 48 P.M. | 4h. 37m. P.M. |
| | | | | **1894.** | |
| 4 | 55 | III. | 22 | 10 37 A.M. | 10h. A.M. |
| 5 | 61 | VII. | 12 | 2 17 P.M. | 1h. 10m. P.M. |
| | | | | **1895.** | |
| 6 | 65 | I. | 18 | 2 37 P.M. | 55m. P.M. |
| 7 | 67 | VIII. | 9 | 5 38 P.M. | 1h. 5m. P.M. |
| | | | | **1897.** | |
| 8 | 77 | I. | 10 | 9 18 P.M. | 8h. 35m. P.M. |
| 9 | 18 | IX. | 21 | 5 28 A.M. | 1h. 10m. P.M. |

To the above is added a magnetometer disturbance, April 14, 1895, 10 hrs. 22 mins. P.M., which probably corresponds to an earthquake *felt* and recorded throughout many parts of Italy, April 14, at 10 hrs. 18 mins. (in Rome). The origin of this was near Laibach, in Austria.

For the earthquakes recorded but not felt in Europe, the Pola disturbances, with one exception, are from one to four hours in advance of the seismograph records.

*Meteorological Office, Toronto, Canada. Director,* Professor R. F. STUPART.

Professor Stupart writes me that he has compared the list of earthquakes with the magnetometer traces prior to their disturbance by the electric trams, and does not find upon them any irregularities at the specified times.

*Magnetometer Disturbances recorded at Bombay Government Observatory.*
N. A. F. MOOS, *Director.*

In the list on p. 238 the earthquakes referred to are those which were recorded in Europe. Several of these had submarine origins the positions of which are unknown (see List, p. 227).

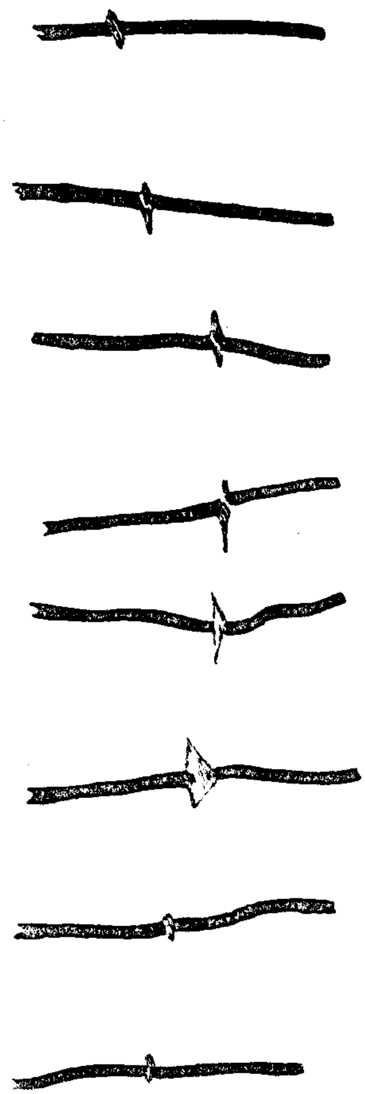
The peculiarity of the movements of the magnets, the fact that they are disturbed by movements which are not perceptible, that the same movements originated at great distances, and that in some instances they

*Government Observatory, Bombay. Magnetograph Disturbance, presumably due to Seismological Disturbance.* N. A. F. Moos, *Director.*

| No. at Government Observatory, Colaba | Corresponding Slide No. | Date on which there was vibration | Time G.M.T. Civil 0 or 24 hour equal to midnight | Instruments Affected. H = Horizontal Force D = Declination V = Vertical Force | Approximate amplitudes of vibration of H in C.G.S. units: Increasing | Approximate amplitudes of vibration of H in C.G.S. units: Decreasing | Remarks |
|---|---|---|---|---|---|---|---|
| | | | H. M. | | | | |
| 1 | | 1889, February 16 | 8 52 A.M. to 10 29 „ | H | ·00005 | ·00005 | 5 very small shocks at intervals. Earthquake records not commenced. |
| 2 | 2 | „ July 12 | 7 46 A.M. | H+D | ·00007 | ·00007 | Small. Vibration trace slant-wise, presumably due to vibration, first performed round a raised zero (increasing H F) and latterly round lowered zero. Quetta earthquake, July 11, 10h. 22m. P.M., to July 12, 5h. 22m. A.M. |
| 3 | | „ August 7 | 7 49 „ | H+D | ·00007 | ·00012 | Lower amplitude good deal larger. |
| 4 | | „ „ 8 | 1 19 P.M. | H+D | ·00007 | ·00009 | Small. |
| 5 | | „ „ 21 | 0 25 „ | H+D | ·00005 | ·00007 | Very small. |
| 6 | | „ „ 22 | 0 17 „ | H+D | ·00005 | ·00006 | „ „ |
| 7 | | „ „ 23 | 1 29 „ | H | ·00005 | ·00006 | „ „ |
| 8 | | 1890 „ 2 | 6 11 „ to 6 15 „ | H+D+V | ·00012 | ·00010 | All instruments affected. Strongly marked. |
| 9 | | 1891, March 7 | 6 17 A.M. | H | ·00007 | ·00007 | Feeble, but well marked. } No earthquake observations during this period. |
| 10 | | „ April 11 | 4 49 „ | H | ·00009 | ·00010 | Small and well marked. |
| 11 | | „ May 6 | 5 44 P.M. | H | ·00007 | ·00005 | Very small, not well marked. |
| 12 | | „ June 8 | 7 57 A.M. | H+D | ·00011 | ·00010 | Strong, very well marked. |
| 13 | | 1892, May 16 | 2 16 „ | H | ·00011 | ·00020 | Feeble, but very well marked. Large eqke., May 17, 1h. 41m. to 4h. 43m. P.M. |
| 14 | | „ October 16 | 6 19 „ to 6 57 „ | H | ·00006 | ·00009 | 4 separate and distinct shocks. Earthquake, 11h. 52m. to 13h. 40m. P.M., on October 17. |
| 15 | | 1893, January 11 | 8 30 P.M. | H | ·00021 | ·00025 | Strong and very well marked. Beginning abrupt and sudden. Earthquake, January 11, 1h. 18m. P.M. |
| 16 | 21, 22 | „ February 9 | 8 10 A.M. | H+D | ·00008 | ·00008 | Very feeble and faintly marked. Large earthquake, February 9, 6h. 13m. to 8h. 28m. P.M. Origin, Turkey or Japan. |
| 17 | | „ October 8 | 11 26 „ | H | ·00004 | ·00005 | Very faint and feebly marked. |
| 18 | | „ November 5 | 4 2 „ to 4 9 „ | H | ·00014 | ·00012 | Heavy and well marked. Beginning gradually and coming to a maximum within 2 minutes after commencement, and then gradually subsiding. Large earthquake, 3h. 56m. to 6h. 0m. A.M. Origin, Tashkent. |
| 19 | | 1895, February 7 | 2 14 P.M. | H+D | ·00005 | ·00004 | } Feeble. |
| 20 | | „ „ „ | 3 14 „ to 3 19 „ | H | ·00005 | ·00005 | |
| 21 | | „ „ „ | 3 29 „ | H | ·00006 | ·00006 | |
| 22 | | „ „ 20 | 9 44 „ | H+D+V | ·00010 | ·00021 | All instruments affected. Well marked. |
| 23 | | „ „ 26 | 7 58 A.M. | H | ·00006 | ·00005 | Small. |
| 24 | | 1896, February 13 | 8 21 „ | H+D | ·00005 | ·00009 | Well marked. |
| 25 | | „ March 16 | 5 29 P.M. to 5 33 „ | H | ·00011 | ·00013 | Well marked and heavy. |
| 26 | 72 | „ May 28 | 0 24 „ | H | ·00006 | ·00006 | Small. |
| 27 | | „ „ „ | 4 23 „ | H | ·00005 | ·00005 | „ |
| 28 | | „ „ „ | 4 31 „ | H | ·00005 | ·00006 | „ |
| 29 | | „ „ 31 | 0 30 „ | H | ·00007 | ·00007 | Small and feeble. |
| 30 | 72 | „ August 31 | 11 29 A.M. to 11 31 „ | H+D | ·00005 | ·00006 | Small. August 31, earthquake, 8h. 23m. A.M.; duration, 2 hours. |
| 31 | | „ October 31 | 11 17 „ | H | ·00005 | ·00005 | Small. October 30, 11h. 50 m. P.M. to 0h. 20m. A.M. on the 31st. Also November 1, 5h. 5m. A.M.; duration, 2 hours. |
| 32 | | „ „ „ | 0 46 P.M. | H | ·00005 | ·00005 | Small. |
| 33 | | „ „ „ | 1 39 „ | H | ·00004 | ·00004 | „ |
| 34 | 81 | 1897, September 21 | 5 49 A.M. | H | ·00007 | ·00007 | „ well marked. Sept. 21, earthquake, 5h. 28m. A.M. Origin, Borneo. |
| 35 | | „ „ 29 | 0 16 P.M. | H | ·00005 | ·00004 | „ „ „ |
| 36 | | „ December 4 | 3 54 .. | H | ·00005 | ·00004 | „ „ „ |

were but feebly pronounced near to their origins, inclines Mr. Moos to the opinion that the disturbances are at least partly magnetic.

FIG. 6.



No. 2, July 12, 1889.

No. 3, Aug. 7, 1889.

No. 12, June 8, 1891.

No. 13, May 16, 1892.

No. 15, Jan. 11, 1893.

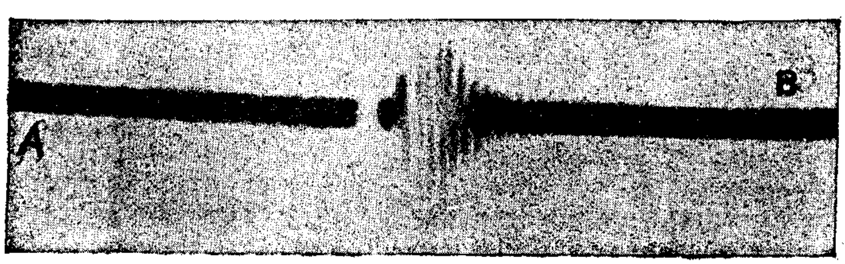
No. 18, Nov. 5, 1893.

No. 34, Sept. 21, 1897.

Usual type.

Sketches of Magnetometer Disturbances recorded at Bombay. N. A. F. Moos.

FIG. 7.




Bombay, June 12, 1897. Disturbance of Declination Needle. Multiplication, $2\frac{1}{2}$ times. N. A. F. Moos.

In the Bombay Magnetic and Meteorological Observations Mr. Moos describes in some detail the disturbances he noted in connection with the Assam earthquake of June 12, 1897.

Dines' Pressure Tube Anemometer Chart did not show any trace of atmospheric disturbance. The barograph trace was, however, disturbed, the maximum effect being about 1 min. later than the maximum disturbances in the declination and vertical force magnetograms. These instruments are of the Kew pattern. The needle of the declinometer has a period of 5·33 seconds, and the disturbance it suffered is here shown enlarged about $2\frac{1}{2}$ times. The time of vibration of the needle of the horizontal force magnetograph, which shows an equally large disturbance, is 8 seconds. The disturbance in the vertical force magnetograph, which is also pronounced, continued over three minutes. There are fourteen fairly regular waves in 29 mins.; that is, the magnet which, if mechanically disturbed and allowed to return to rest, would do so in double swings of 5·33 secs. came to rest with periodic movements, each of which had a duration of two minutes. In Europe the earth-waves from the earthquake had periods of from 10 to 15 secs., and it is likely that when they passed Bombay their periods would be about five seconds. It is difficult to understand how a movement of this description would result in the displacements recorded; and, as Mr. Moos points out, it is equally difficult to see why earth-waves could mechanically cause a change in the scale reading of this type of instrument. His conclusion is that the seismic convulsion was in some way the cause of a magnetic action, every seismic wave having its companion effect in a magnetic wave.

The following is a summary of disturbances of magnetic needles at various observatories by the shock of June 12, 1897 (see Earthquake No. 105, p. 204):—Time at origin, about 11 hrs. 4 mins. A.M.; arrival of preliminary tremors in Europe, about 11 hrs. 17 mins.; arrival of large waves in Europe, about 11 hrs. 47 mins.

| Place | D | H | V | Remarks |
|---|---|---|---|---|
| | H. M. H. M. | H. M. H. M. | H. M. H. M. | |
| Bombay . | 11 14–11 16<br>11 17–11 43 max. | 11 11–11 14<br>11 45 End | 11 14–11 19<br>11 19–11 23 | 1st Shock<br>2nd Shock |
| Batavia . | 11 22 | 11 23, 11 34,<br>11 37, 11 54 | 11 29 max. | 4 Shocks for H |
| Utrecht . | 11 17–11 19 max.<br>11 45–12 30 | 11 45–12 20<br>12 35– 1 30 | | D has two max. of 10 & 15 mm., which for H are 10 & 7 mm. |
| Wilhelmshaven | 11 19–11 25<br>11 44–12 0 | 11 18–11 39 | 11 26–11 59 | |
| Pawlowsk | | 11 17–11 25<br>11 19–11 42 | | Max. of H at 11h. 22m. |
| Para Saint Maur | 11 27 | 11 27 | | Small |
| Kew . . | | | | Small & doubtful |
| Copenhagen | | | | Disturbed |

Magnetographs at Lyons, Perpignan, Pola, Vienna, Uccle, and Lisbon were not disturbed.

The barograph disturbance at Bombay was at 11 hrs. 14 mins. to 11 hrs. 21 mins., with max. at 11 hrs. 13 mins.; the electrometer disturbance at Batavia was at 11 hrs. 16 mins. (exact).

*Magnetometer Disturbances recorded at the Royal Alfred Observatory, Mauritius. Disturbances are indicated as: s = small; vs = very small; a = abrupt; va = very abrupt; sa = small abrupt. Director*, T. F. CLAXTON, Esq.

| No. | No. on list p. 227 | Month | Day | Time of Earthquake | Magnetic Disturbances |
|---|---|---|---|---|---|
| | | | | **1889** | |
| 1 | 1 | IV. | 18 | 5 21 A.M. | H 7h. 35m. A.M.–8h. 10m. vs, 9h. 45m.–10h. 0m. vs, 11h. 10m.–13h. 10m. |
| 2 | 2 | VII. | 11 | 10 22 P.M. | H 3h. 40m. P.M.–4h. 40m. vs, 5h. 30m.–6h. s, 7m. vs. V 3h. 40m.–6h. 10m. vs |
| 3 | 3 | VII. | 28 | 3 30 P.M. / 6 0 P.M. | H 5h. 50m. P.M.–6h. 20m. vs, 7h. 10m.–9h. 10m. vs, 10h. 10m. to 2 A.M. on 29th, vs |
| 4 | 5 | VIII | 25 | 7 37 P.M. | H 3h. 40m. P.M.–5h. 20m. vs, 5h. 50m.–6h. 40m., 7h. 37m.–9h. 10m. vs. V 4h. 10m.–8h. 10m. vs |
| | | | | **1891** | |
| 5 | 6 | X. | 27 | 9 38 P.M. | H 4h. 40m. P.M.–5h. 40m., 7h. 30m.–8h. 10m. s. D 4h. 46m. vs–7h. 35m. vs |
| | | | | **1892** | |
| 6 | 7 & 8 | III. | 16 | 1 22 P.M. / 5 22 P.M. | H 15d. 8h. 40m. P.M.–9h. 20m. V 9h. 10m.–9h. 20m. a |
| 7 | 11 | X. | 19 | 4 21 A.M. | H 7h. 0m. A.M.–7h. 40m. vs. D 4h. 10m.–5h. 40m. vs. V 4h. 40m.–5h. 10m., 7h. 0m.–7h. 40m. vs |
| 8 | 12 | XI. | 4 | 5 24 P.M. | H 2h. 28m. A.M.–5h. 40m. vs. D, like H, also on the 5th. V, like H, also on the 5th, sa |
| 9 | 14 | XII. | 9 | 1 19 A.M. | H 8d. 8h. 10m. A.M. and 11h. 10m.–5h. 10m. P.M. s. D like H, but vs. V 8h. 10m.–1h. 10m. P.M. |
| | | | | **1893** | |
| 10 | 16 | I. | 28 | 11 46 P.M. | H 7h. 25m. P.M.–11h. 10m. vs, 29d. 9h. 10m. a. V 7h. 38m. P.M.–7h. 43m., 8h. 10m.–8h. 20m. |
| 11 | 19 | II. | 6 | 5 7 P.M. | H 1h. 10m. P.M.–7d. 9h. 10m. A.M. vs |
| 12 | 21 | — | 9 | 6 13 P.M. | H 6h. 10m. P.M.–7h. 10m. vs, a wave |
| 13 | 22 | — | 9 | 9 40 P.M. | H 10h. 10m. P.M.–10h. 40m. vs, 10d. 0h. 10m. A.M. vs, 1h. 40m. vs. D 10d. 4h. 10m. a–5h. 10m. vs |
| 14 | 24 | — | 13 | 5 0 P.M. | H 4h. 10m. P.M.–5h. 10m. vs. D 11h. 50m. A.M.–12h. 0m. vs |
| 15 | 25 | — | 16 | 5 17 A.M. | D 15d. 4h. 10m. A.M. s–8h. 40m. vs, 9d. 40m. P.M.–11h. 40m. vs, 16d. 1hr. 10m. A.M.–5h. 10m. s. V 15d. 9h. 40m. P.M.–10h. 40. H, a small magnetic disturbance, February 14–18 |
| 16 | 30 | III. | 2 | 11 6 A.M. | H 11h. 0m. P.M.–0h. 10m. A.M. shallow wave |
| 17 | 31 | — | 14 | 6 20 A.M. | H 5h. 50m. A.M.–1h. 11m. P.M. |
| 18 | 33 | — | 23 | 8 43 P.M. | H 5h. 40m. P.M. s |
| 19 | 34 | IV. | 8 | 1 51 P.M. | H 5h. 10m. A.M.–11h. 10m. s. D like H but faint |
| 20 | 35 | — | 17 | 5 48 A.M. | D 4h. 40m. A.M. vs |

MAGNETOMETER DISTURBANCES RECORDED AT THE ROYAL ALFRED OBSERVATORY, MAURITIUS—*continued.*

| No. | No. on list p. 227 | Month | Day | Time of Earthquake | Magnetic Disturbances |
|---|---|---|---|---|---|
| 21 | 37 | — | 29 | 6 2 P.M. | H 6h. 40m. P.M. vs |
| 22 | 39 | V. | 18 | 2 39 P.M. | H 9h. 40m. A.M. s–1h. 10m. P.M. vs, 2h. 40m.–3h. 25m. s. D 1h. 10m. P.M.–4h. 10m. P.M. vs |
| 23 | 41 | — | 23 | 8 38 P.M. | H 10h. 25m. P.M.–11h. 10m. s wave. D same as H, but vs wave |
| 24 | 42 | VI. | 3 | 4 25 P.M. | H 2d. 10h. 10m. p.m.–3d. 0h. 10m. A.M. vs, 0h. 40m. A.M.–2h. 10m. vs |
| 25 | 44 | — | 11 | 9 9 P.M. | H 8h. 10m. P.M.–10h. 10m. s wave. D same as H, but vs wave |
| 26 | 52 | VIII. | 6 | 7 42 P.M. | H 4h. 45m. A.M., 7h. 40m.–8h. 10m. va, and movements until 4h. 11m. P.M. D like H, but not abrupt |
| | | | | | **1894** |
| 27 | 55 | III. | 22 | 10 37 A.M. | H small movements all day. Active from 8h. 10m. A.M.–9h. 10h., but vs. D same as H |
| 28 | 58 | IV. | 29 | 3 25 A.M. | H 28d. 4h. 10m. P.M.–5h. 10m. P.M. s, 29d. 8h. 10m. A.M–10h. 10m. A.M., 11h. 10m.–0h. 10m. P.M. vs, 0h. 30m. P.M.–2h. 10m. vs, 6h. 50m. 8h. 10m. D 29d. 8h. 10m. A.M.–10h. 10m. vs, 6h. 50m. P.M.–8h. 10m. vs. V occasional small movements, 29d. 8h. 10m. A.M.–3h. 10m. P.M. |
| 29 | 59 | VI. | 20 | 5 45 A.M. | H 19d. 4h. 10m. P.M. sa, 21d. 1h. 0m. A.M. D 20d. 4h. 10m. A.M.–8h. 10m. s. V 20d. 7h. 40m. A.M. vs |
| 30 | 62 | IX. | 7 | 11 40 A.M. | H 11h. 40m. vs |
| 31 | 64 | — | 27 | 9 8 P.M. | H 8h. 15m. P.M.–11h. 40m. s wave. D like H. V like H, but vs |
| | | | | | **1895** |
| 32 | 65 | I. | 18 | 2 37 P.M. | H 9h. 10m. A.M. – 1h. 25m. P.M. vs tremors, 4h. 10m. P.M.–6h. 10m. P.M. wave, 8h. 10m. P.M.–9h. 10m. P.M. D 2h. 10m. A.M.–4h. 10m. A.M. vs. V 8h. 10m. P.M.–9h. 10m. P.M. s wave |
| 33 | 66 | VII. | 8 | 10 43 P.M. | H 9d. 4h. 10m. A.M.–7h. 40m., 9h. 10m.–4h. 10m. P.M., 5h. 10m. P.M.–7h. 25m., 8h. 25m.–10h. 25m. vs tremors |
| 34 | 67 | VIII. | 9 | 5 38 P.M. | H 5h. 10m. P.M.–7h. 10m. vs, 9h. 25m. P.M.–0h. 25m. A.M. vs |
| 35 | 68 | XI. | 13 | 9 31 P.M. | H 7h. 40m. P.M.–8h. 40m. P.M. wave, 10h. 10m. to midnight occasional s tremors. D 7h. 40m. P.M.–8h. 40m. P.M. s wave. V like D |
| | | | | | **1896** |
| 36 | 69 | VI. | 16 | 11 46 A.M. | H 7h. 40m. A.M.–10h. 10m. P.M., a small disturbance. D and V like H |
| 37 | 70 | VI. | 29 | 9 2 P.M. | H 12h. 10m. P.M.–30d. 1h. 10m. A.M., slight movements |
| 38 | 72 | VIII. | 31 | 8 23 A.M. | V 29d. 11h. 10m. P.M.–30d. 0h. 10m. A.M., 8h. 10m. A.M.–9h. 10m. A.M. |
| 39 | 75 | IX. | 22 | 4 53 A.M. | V 4h. 10m. A.M.–5h. 10m. vs |

MAGNETOMETER DISTURBANCES RECORDED AT THE ROYAL ALFRED OBSERVATORY, MAURITIUS—*continued.*

| No. | No. on List p. 227 | Month | Day | Time of Earthquake | Magnetic Disturbances |
|---|---|---|---|---|---|
| | | | | **1897** | |
| 40 | 77 | I. | 10 | 9 18 P.M. | H 4h. 40m. P.M. va, small distance after until midnight. V like H |
| 41 | 78 | VI. | 12 | 11 29 A.M. | H 2h. 10m. P.M. a |
| 42 | 80 | IX. | 20 | 7 24 P.M. | D 4h. 10m. A.M.–5h. 10m. vs |
| 43 | 81 | IX. | 21 | 5 28 A.M. | H 5h. 40m. A.M.–10h. 10m. vs |
| 44 | 83 | XII. | 29 | 11 40 A.M. | H small disturbance all day, sharp at 4h. 15m. P.M.–4h. 35m V like H, only very small |

An examination of the above table, for which I am indebted to Mr. T. F. Claxton, the Director of the Royal Alfred Observatory, shows the following results :—

Cases in which magnetic needles have been disturbed at intervals varying between a few minutes and 30 hours *before* an earthquake, 32.

Cases in which magnetic needles have been disturbed at intervals varying between a few minutes and 6 hours *after* an earthquake, 11.

Case in which the disturbances of magnetic needles have accompanied an earthquake, 1.

*Observations at the Magnetic and Meteorological Observatory, Batavia.* *By* Dr. J. P. VAN DER STOK.

*June* 12, 1897 (Assam Earthquake) (see Earthquake No. 105).

| | G.M.T. H. | M. | S. |
|---|---|---|---|
| Horizontal Force, first shock | 11 | 23 | 40 A.M. |
| " " second " | 11 | 34 | 40 |
| " " third " | 11 | 37 | 40 |
| " " last " | 11 | 54 | 40 |
| Declination, mid. of motion | 11 | 22 | 40 |
| Vertical Force, maximum | 11 | 29 | 40 |
| Electrometer (Mascart), exact commencement | 11 | 16 | 40 |

*September* 20, 1897 (see Earthquake No. 133).

| | H. | M. | S. | |
|---|---|---|---|---|
| Horizontal Force | 7 | 16 | 20 P.M. | very small. |
| Electrometer | 7 | 14 | 20 | large. |

The declinometer and balance were not disturbed.

*September* 21, 1897 (see Earthquake No. 134).

| | H. | M. | S. | H. | M. | S. | H. | M. | S. |
|---|---|---|---|---|---|---|---|---|---|
| Horizontal Force | 5 | 19 | 20 A.M. | 5 | 24 | 20 | | | |
| | 5 | 25 | 20 | 5 | 30 | 20 | 5 | 33 | 20 |
| | 5 | 39 | 20 and | 5 | 42 | 20 | | | |
| Declination at | 5 | 26 | 20 A.M. slight. | | | | | | |
| Vertical Force | 5 | 23 | 20 (maximum). Duration 20 mins. | | | | | | |
| Electrometer | 5 | 21 | 20 A.M. (commencement). | | | | | | |

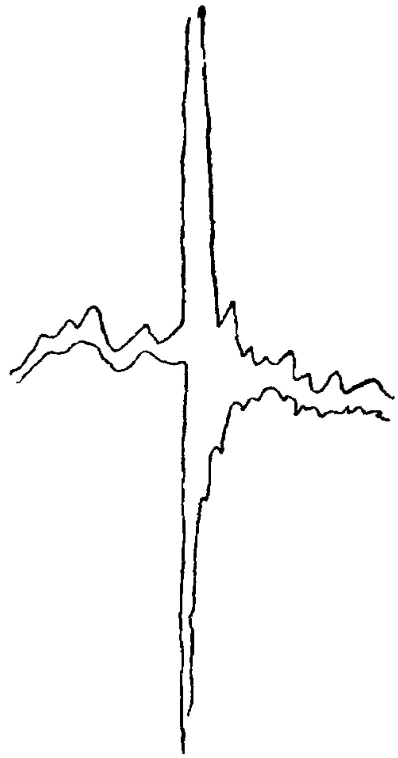
The distance from Batavia to the origin of these last two disturbances is 1,500 kms. The last of them also disturbed magnetometers in the Mauritius, Bombay, Pola, and Utrecht.

R 2

FIG. 8.

Bifilar, Sept 20. Eqke. 133.

Electrometer, Sept. 20. Eqke. 133.



Electrometer, Sept. 21. Eqke. 134.

Bifilar, June 12. Eqke. 105.

Bifilar, Sept. 21. Eqke. 134.

Vertical Force, June 12. Eqke. 105.

Magnetometer and Electrometer disturbances. Batavia, 1897.

*Magnetometer Disturbances noted at the Magnetisch en Meteorologisch Observatorium, Batavia.*

| No. | No. on List p. 227 | Month | Day | Hour | Magnetometer Disturbances |
|---|---|---|---|---|---|
| | | | | **1892** | |
| | | | | H. M. | |
| 1 | 15 | XII. | 20 | 0 34 A.M. | Dec. 19, 11h. 3m. P.M. Very slight. |
| | | | | **1893** | |
| 2 | 21 | II. | 9 | 6 13 P.M. | 6h. 19m. P.M. Pretty distinct. |
| | | | | **1895** | |
| 3 | 65 | I. | 18 | 2 37 P.M. | 2h. 14m. P.M. Faint (?). |
| 4 | 66 | VII. | 8 | 10 43 P.M. | 4h. 5m. P.M. to 4h. 11m. P.M. Clear (?). |

MAGNETOMETER DISTURBANCES NOTED AT BATAVIA—*continued.*

| No. | No. on List p. 227 | Month | Day | Hour | Magnetometer Disturbances |
|---|---|---|---|---|---|
| | | | | **1896** | |
| 5 | 71 | VIII. | 26 | 11 22 P.M. | 2h. 45m. P.M. and 2h. 49m. P.M. |
| 6 | 76 | XI. | 1 | 5 18 A.M. | Nov. 2, 11h. 58m. A.M. to 0h. 8m. P.M. (?) |
| | | | | **1897** | |
| 7 | 78 | VI. | 12 | 11 29 A.M. | 11h. 25m. A.M. to 11h. 50m. A.M. Strong. |
| 8 | 80 | IX. | 20 | 7 24 P.M. | 7h. 17m. P.M. to 7h. 33m. P.M. Not strong. |
| 9 | 81 | IX. | 21 | 5 28 A.M. | 5h. 24m. A.M. to 5h. 45m. A.M. Strong. |

*Magnetometer Disturbances noted at the Observatory, Zikawei, China.*

| No. | No. on List p. 227 | Month | Day | Hour | Magnetometer Disturbances |
|---|---|---|---|---|---|
| | | | | **1889** | |
| | | | | H. M. | |
| 1 | 1 | IV. | 18 | 5 21 A.M. | 2h. 54m. and 4h. 24m. Small serrations. |
| 2 | 4 | VII. | 28 | 6 0 P.M. | 4h. 49m. to 1h. 54m. Small notched movements. |
| | | | | **1891** | |
| 3 | 6 | X. | 27 | 9 38 P.M. | 9h. 39m. A remarkable mechanical disturbance. See 'La Nature,' 1892, No. 975, p. 149. |
| | | | | **1892** | |
| 4 | 7 | III. | 16 | 1 22 P.M. | 1h. 54m. to 5h. 54m. Slight agitation. |
| 5 | 11 | X. | 19 | 9 41 A.M. | Perturbations the day before and after. On the 4th, perturbations from 2h. 9m. A.M. |
| | | | | **1893** | |
| 6 | 19 | II. | 6 | 5 7 P.M. | 3h. 54m., trepidations. Large perturbations at 5h. 27m. |
| 7 | 24 | II. | 13 | 5 0 P.M. | 4h. 14m. to 5h. 4m. Slight undulations. |
| 8 | 25 | II. | 16 | 5 17 A.M. | All day on the 16th and 17th a great perturbation, but nothing exceptional at the time of the earthquake. |
| 9 | 44 | VI. | 11 | 9 9 P.M. | 3h. 54m. to 9h. 9m. Light undulations. |
| 10 | 53 | VIII. | 10 | 9 9 P.M. | 3h. 54m. to 7h. 54m. Small serrations. |
| | | | | **1894** | |
| 11 | 55 | III. | 22 | 10 37 A.M. | Great perturbations on the 22nd and 23rd, but nothing special at the time of the earthquake. |
| 12 | 59 | VI. | 20 | 5 45 A.M. | Two days of remarkable perturbations, but nothing remarkable at the time of the earthquake. |
| 13 | 62 | X. | 7 | 11 40 A.M. | 9h. 54m. A.M. to 3h. 54m. P.M. Slight serrations. |
| 14 | 64 | X. | 27 | 9 8 P.M. | 3h. 54m. to 9h. 54m. Marked oscillations. |
| | | | | **1895** | |
| 15 | 65 | I. | 18 | 2 37 P.M. | 11h. 54m. to 1h. 54m. Several insignificant movements. |
| 16 | 67 | VIII. | 9 | 5 38 P.M. | At 3h. 54m. a disturbance lasting two days began. |

Father Chevalier, who kindly sent me the above notes, remarks that the most striking feature of the comparison appears to be that there is no relation between earthquakes and magnetic disturbances. A slight earthquake which was felt at Zikawei on June 4, 1898, was, however, recorded by a mechanical motion of the magnetic needles. In the sixteen cases where something has been noted at or about the time of large earthquakes, it must be observed that eleven of these refer to disturbances which originated in Japan or Manila, and in nine of these eleven cases perturbations preceded the occurrence of the earthquakes. We have here something analogous to what has been observed in Japan. If we omit the three instances (nine, ten, and sixteen) where there have been slight movements of the magnetic needles at about the time when small shocks were recorded in Italy, it hardly appears to be a mere coincidence that the Zikawei register is practically confined to records of earthquakes which have originated in localities not far removed from that observatory. If it were a coincidence, then we should expect to find similar perturbations preceding at least a few of the remaining sixty-seven earthquakes on our list. Inasmuch as certain of these earthquakes, as, for example, those originating in Borneo and N.E. India, in every probability gave rise to as much mechanical movement at Zikawei as those originating in Japan, it seems that the instruments at that station are but very rarely disturbed by the mere movement of the ground.

*Extracts from the 'Bollettino della Società Sismologica Italiana,'* 1895, 1896, 1897.

| No. | Nos. corresponding to those in List p. 227 | Earthquake | | | | Magnetograph Disturbances |
|---|---|---|---|---|---|---|
| | | Month | Day | Hour | Place of Observation | |
| | | | | **1895** | | |
| | | | | H. M. | | Place |
| 1 | | III. | 6 | 9 28 A.M. | Rome | Potsdam = 0. |
| 2 | | VI. | 15 | 4 26 P.M. | ,, | Utrecht. Magnetographs disturbed 4h. 5m. P.M.<br>No disturbances at Pola, Potsdam, Pawlowsk, Wilhelmshaven, Toronto, Stonyhurst, and Vienna. |
| 3 | 66 | VII. | 8 | 10 43 P.M. | Padua | Pawlowsk. D and H disturbed.<br>Potsdam. D, 10h. 44m. H, 10h. 50m. V, 10h. 50m.<br>*Wilhelmshaven. D, 10h. 47m.* HF, 10h. 49m. V, 10h. 40m.<br>Utrecht. D, 10h. 27m. H, 10h. 26m.<br>Pola. D, 10h. 52m.<br>Toronto, Stonyhurst, and Vienna = 0. |
| 4 | | XI. | 2 | 0 25 A.M. | Rome | Potsdam. V, 32m. to 35m. Amplitude 1′. |

**Extracts from the 'Bollettino della Societa Sismologica Italiana,' 1895–7—*continued*.**

| No. | Nos. corresponding to those in List p. 227 | Earthquake | | | | Magnetograph Disturbances |
|---|---|---|---|---|---|---|
| | | Month | Day | Hour | Place of Observation | |
| | | | | **1896** | | |
| 5 | | I. | 9 | 12 14 P.M. | Rome | Potsdam. V, 2h. 8m., 2h. 13m., and 2h. 18m. |
| 6 | | III. | 4 | 4 33 A.M. | ,, | Potsdam. D, 2h. 52m. to 5h. 9m. H, 4h. 43m. to 5h. 2m. V, 4h. 50m. to 4h. 56m.<br>Utrecht. D slight. H, 4hr. 55m. to 5h. 23m. |
| 7 | | IV. | 10 | 9 28 A.M. | ,, | Potsdam. V, 9h. 38m. to 9h. 42m. Amplitude about 0′·5. |
| 8 | | V. | 2 | 1 21 P.M. | ,, | Potsdam and Utrecht = 0. |
| 9 | | | 3 | 2 55 P.M. | ,, | ,, ,, ,, ,, |
| 10 | | | 5 | 11 39 P.M. | ,, | ,, ,, ,, ,, |
| 11 | 69 | VI. | 15 | 11 19 A.M. | ,, | Utrecht. D, 11h. 23m. to 11h. 46m. H, 11h. 26m. to 12h. 16m. |
| 12 | 71 | VIII. | 26 | 11 23 P.M. | ,, | Wilhelmshaven. D, 11h. 28m. to 11h. 31m. H, 11h. 29m. to 11h. 32m. V, 11h. 25m. to 11h. 44m.<br>Utrecht. D, 11h. 29m. to 11h. 49m. H, 11h. 27m. to 11h. 55m.<br>Potsdam. D, 11h. 31m. to 11h. 59m. Amplitude 2′·5.<br>Potsdam. H, 11h. 29m. to 11h. 40m. Amplitude 1′.<br>Potsdam. V, 11h. 35m. to 11h. 37m. the maximum. |
| 13 | | | 27 | 11 0 A.M. | ,, | Wilhelmshaven. All three instruments disturbed at 10h. 57m., 11h., and 11h. 1m.<br>Utrecht. D, 10h. 53m. to 11h. 6m. H, 10h. 54m. to 11h. 3m.<br>Potsdam. D, 11h. 2m. to 11h. 35m. H, 11h. 7m. V, 11h. 5m. |
| 14 | 72 | | 31 | 8 21 A.M. | ,, | Wilhelmshaven. D, 8h. 54m. to 9h. 2m. H, 8h. 56m. to 9h. 9m. V, 8h. 30m.<br>Potsdam and Utrecht no disturbance. |
| 15 | 73 | IX. | 6 | 0 2 A.M. | ,, | Wilhelmshaven. D, 29m. to 13m. H, 7m. to 10m. V, 4m. to 29m.<br>Utrecht. D, 6m. to 19m. H, 7m. to 31m.<br>Potsdam. D, 12m. to 24m. H, 11m. to 24m. Amp. 2′. V, 12m. to 20m. |
| 16 | | | 12 | 8 24 A.M. | ,, | Wilhelmshaven. D, 8h. 51m. to 8h. 54m. H = 0. V, 8h. 30m. to 9h. 1m.<br>Potsdam and Utrecht = 0. |

**Extract from the 'Bollettino della Società Sismologica Italiana,' 1895–7—*continued*.**

| No. | Nos. correspond-ing to those in List p. 227 | Earthquake Month | Day | Hour | Place of Observation | Magnetograph Disturbances |
|---|---|---|---|---|---|---|
| 17 | 75 | | 22 | 4 53 A.M. | " | Wilhelmshaven. D and H = 0. V, 5h. 3m. to 5h. 12m. Potsdam. D, 5h. 4m. to 5h. 20m. H, 5h. 5m. V, 5h. 7m. (?). Utrecht = 0. |
| 18 | | | 23 | 11 52 P.M. | " | Wilhelmshaven. D, 3m. to 4m. H = 0. V, 11h. 58m. to 17m. Potsdam. D, 4m. to 14m. H, 9m. to 13m. V (?) Utrecht = 0. |
| 19 | 76 | XI. | 1 | 5 7 A.M. | " | Wilhelmshaven. D, 5h. 27m. to 5h. 28m. V, 5h. 22m. to 5h. 38m. Potsdam. D, 5h. 21m. to 5h. 41m. H, 5h. 50m. to 5h. 35m. V, 5h. 26m. to 5h. 35m. Utrecht. D, 5h. 30m. to 5h. 46m. H, 5h. 27m. to 5h. 53m. |
| 20 | | | 10 | 10 43 A.M. | " | Wilhelmshaven, Potsdam, Utrecht = 0. |
| | | | | **1897** | | |
| 21 | | II | 7 | 7 59 A.M. | Shide | Utrecht = 0. |
| 22 | | | 15 | 10 20 P.M. | Potsdam | " " |
| 23 | | | 19 | 8 59 P.M. | Rome | Potsdam. V, 9h. 41m. to 9h. 44m. Amplitude 1′. |
| 24 | | | 20 | 0 18 A.M. | Shide | Utrecht = 0. |

Until magnetograph records have been obtained from other observatories, and until special experiments have been made, as, for example, to determine the effect of artificially produced earthquake-like motion upon magnetic needles and the effect of actual earthquakes upon non-magnetic bars so suspended that their periodic movements are identical with those of magnetic needles upon the same supporting pier, we cannot say with certainty whether earthquake waves are or are not accompanied by magnetic waves.

In discussing the records brought together, which refer to the movements of magnetic needles *at the time of* earthquakes, it is important to consider the mechanical movements which occurred at the time of their production.

When a great earthquake has originated, as, for example, in Japan, seismographic records indicate that about 16 mins. later Europe has been swept with a flood of motion, and it might be imagined that one observatory has practically been subjected to as much movement as any other.

*The effects on magnetic needles at various observatories have, however,* been very different.

At magnetic observatories in England, Pola, Vienna, Copenhagen, Toronto, and other observatories only the slightest perturbations are noted, and these only rarely. On the contrary, at Utrecht, Potsdam, and Wilhelmshaven movements of magnetic needles and the occurrence of seismic waves are comparatively of frequent occurrence.

One explanation for this marked difference in the behaviour of magnetic needles at different stations rests on the fact that these three latter stations stand on the vast plain of alluvial drift which stretches from Holland eastwards across Northern Germany into Russia, and it may be assumed that the seismic waves on this ocean-like expanse of soft materials are slower and larger than those exhibited in the harder materials on or near to which other observatories are situated. Exceptions to such an explanation are, however, found in the records from Copenhagen and Zikawei, and before we can say with certainty that there are great differences in the character of the mechanical movements at different stations, seismometric records must be obtained from the same.

Other reasons which may be adduced to explain why at one set of stations magnetic needles are disturbed, whilst at another set they are practically quiescent may be as follows :—

First, we may assume that at one set of stations the needles have periodic movements which more nearly synchronise with the period of the earth waves than those of needles at stations where magnetometer disturbances are rare.

The only notes hitherto collected which bear on this point are contained in the following table, in which the times given are the intervals in seconds taken to complete a double or back-and-forth circular vibration of declination (unifilar) and horizontal force (bifilar) magnetometers :—

| | Unifilar. | Bifilar. |
|---|---|---|
| | s. | s. |
| Stonyhurst | 14·30 | 13·20 |
| Bombay | 5·33 | 8·00 |
| Greenwich | 50·00 | 42·00 |
| There is also an upper declination magnet (for eye observations), with a period for double swing of 61s approximately. | | |
| Vienna | 5·35 | 15·36 |
| Pola | 7·98 | |
| Potsdam | 10·00 | 8·00 |
| Wilhelmshaven | 15·9 | 16·7 |
| Kew | 10·5 | 13·6 |
| Falmouth | 17·0 | 18·8 |
| Antwerp | 14·4 | 18·6 |
| Copenhagen | 7·1 | 4·9 |

The magnet for horizontal force at Antwerp is kept at right angles to the meridian by deflection magnets.

From the table it will be noted that the periods given for Kew, where disturbances at the time of earthquakes are rare, are not very different for those given for Potsdam, where disturbances are frequent.

A very much more important point, however, is that all large earthquakes commence with a series of short-period waves. Five-second periods are marked. These are followed with others having periods of 10 secs., whilst later there may be waves with periods of 20 and even

60 secs. From this it may be assumed that at all observatories, whatever be the period of the magnets, each of them for a considerable interval of time is subjected to identical or nearly identical periodic movements of their supports.

From this we should expect to find that large earthquakes would disturb magnetometers at all stations.

Sometimes the magnetic needles appear to be disturbed by the short-period preliminary vibrations, and at other times by the succeeding long-period earth waves; and the question arises, whether the mechanical movement these represent is likely to establish a rotational movement in a suspended magnet.

If we regard a magnet and its suspension as an ordinary pendulum, then at all stations we should expect to find that the preliminary tremors of an earthquake would establish a swing accompanied by more or less rotation. When, however, we have rotational movements of magnetic needles accompanying the larger earth waves the explanation of this is not so clear. The tilting which such waves represent may, as an illustration, be taken at 10 secs. of arc. For such a tilt a magnet with a suspension of 12 ins. would be displaced through a distance of about one hundredth of a millimetre, and because the movement would be extremely slow, taking from 5 to 10 secs. of time in one direction, it is likely that the magnet would closely follow its point of support.

When movements of this character take place the resultant movement recorded in the photographic film is a displacement having a range of from 2 to 15 mm., indicating that the magnetic needle has rotated through an arc of from 1 to 7 minutes.

To determine whether tilting so slight and so slow results in so much rotation is obviously a matter which without great difficulty may be solved by experiment.

The second assumption to account for the disturbance of magnetographs at certain stations only, is the hypothesis that with regard to the surface of the earth there is an unequal distribution of a subjacent magnetic material the movements of which influence magnets in its vicinity.

On the surface these movements are apparently represented by waves 20 to 50 km. in length and 20 to 50 cm. in height.

To explain the fact that magnetic storms and perturbations so often precede large earthquakes and but seldom appear to precede small ones (see Registers for Greenwich, Utrecht, Mauritius, Zikawei, &c.), we may assume that the earthquake is preceded by chemical, physical, or mechanical changes in the constitution of the materials where it originates. All that we are certain about is that with many earthquakes there have been enormous mechanical displacements of material sufficiently large to disturb the Pacific Ocean for a period of twenty-four hours.

Other earthquakes from submarine centres which have not disturbed oceans, but have created equally large earth waves, indicate equally large subterranean reliefs in strain and material readjustments.

These large earthquakes, originating beneath the bottom of the steeper slopes of the earth's surface, suggest that at such places a secular flow in subterranean material may be in progress, accelerations in which result in violent shaking, which as it radiates is transformed into slow earth waves.

Near to the scene of such subterranean changes, prior to and at the time of the same, magnetic perturbations should be observable. In Japan such appears to have been the case.

The large sudden subterranean adjustments may not occur on the average more than twenty times per year; but if we attribute the smaller earthquakes to similar activities, one of these may, on the average, take place every half-hour; and although none of these latter is likely to produce an appreciable magnetic effect on the surface of our earth, their cumulative effect after a sufficient interval of time, as representing a re-arrangement and new condition of magnetic materials, might possibly result in measurable changes in magnetic elements.

## VII. *Sub-oceanic Changes.*

In Section 9 of the Report for 1897 (p. 181) it was stated that off coast lines there was a tendency for sediments and detritus derived from the land accumulating under the influence of gravity to assume unstable contours. That such contours had an existence was shown by reference to soundings. By excessive deposition of sediments, the sub-oceanic escape of waters from subterranean sources, the sudden release of waters backed up in bays by gales, changes in the magnitude and direction of ocean currents, and by sub-oceanic seismic and volcanic action, sudden and extensive yieldings might take place along the faces of slopes in a critical condition. That such sub-oceanic landslides had often taken place was proved by an appeal to the experience of cable engineers, who often found that cable interruptions were the result of their burial along lengths of several miles, the materials covering the lost sections having fallen from the faces of slopes along the base of which the cables had been laid. In a few instances it was noted that there had been a considerable increase in the depth of the ocean along a line of slip. Many examples were given where cable interruption accompanied an earthquake which had a submarine origin, and therefore it may be presumed that it was the earthquake which caused the landslide beneath the ocean, in the same manner that severe earthquakes result in similar displacements of what are probably much more stable surfaces on the land.

It is believed that most of the deep-water cable interruptions on the west side of South America are attributable to sub-oceanic activities of this description, and it was shown that in the Mediterranean, off the coast of Java, and in other parts of the globe, we had from time to time evidences of a very close relationship between seismic activity and the failure of cables.

The fact that earthquakes originating in deep water, as, for example, at a depth of 4,000 fathoms off the N.E. coast of Japan, have been accompanied by a series of sea waves which may agitate an ocean for 24 hours tells us that there must have been a sudden sub-oceanic displacement of a very large body of material, accompanying some form of bradyseismical adjustment.

Although the earthquakes which result from these sudden movements may not be felt or be recordable on a coast at a distance of 200 or 300 miles from their origin, they may often be noted in the records obtained from instruments which are capable of registering the slower movements of the earth's surface at distances of many thousands of miles from their origin. The object of the following table, the materials for which were almost entirely gathered together by my friend Mr. M. H. Gray, of Silvertown, is to indicate the frequency of sub-oceanic disturbance, but by no means to attribute more than a fractional portion of the same to seismic action. The *hours* at which unfelt earthquakes the origins of which have been at great distances from the stations where they were recorded are given with some accuracy, but the times at which cable interruptions have been notified are some time after the interruptions actually occurred. Only those who are in a position to correct these latter dates, and know the circumstances attending the various failures, can determine which of them are likely to have originated from seismic disturbances.

In order to extend our knowledge of sub-oceanic changes, and throwing more certain light upon operations leading to cable interruption, I shall regard it as a great favour if officers of cable companies who may read this report will send me an exact statement of the times at which failures took place, which we know to have happened at *about* the same time as unfelt earthquakes have been recorded, addressing the same to me at the British Association Rooms, Burlington House, London, W., England.

*Approximate Time of Cable Failures, and exact Greenwich Time of Unfelt Earthquakes.*

| No. | Approximate | | | Name of Cable | Exact time of Earthquakes | |
|---|---|---|---|---|---|---|
| | Month | Day | Time | | Day | Hour, G.M.T., & Remarks |
| | | | | **1897.** | | |
| | | | H. M. | | | |
| 1 | I. | 5 | 4 20 P.M. | Hong Kong-Macao . | 4 | 11h. 22m. A.M., & 10h. 52m. P.M. |
| 2 | II. | 4 | 9 15 A.M. | Grenada-Trinidad . . | 5 | 7h. 52m. A.M. |
| 3 | | | | Maranham-Ceara . . | ,, | ,, |
| 4 | | | | Ceara-Pernambuco . | ,, | ,, |
| 5 | | 6 | 9 5 A.M. | Jamaica-Colon . . . | ,, | ,, |
| 6 | | 10 | 2 55 P.M. | Emden-Vigo . . . . | 7 | 7h. 59m. 3s. A.M. |
| 7 | | 23 | | Tenedos-Dardanelles . | { 20<br>21 | 0h. 17m. 47s. A.M.<br>3h. 22m. 0s. A.M. } |
| 8 | | 20 | 3 20 P.M. | Assab-Massowah . . | ,, | ,, |
| 9 | III. | 23 | | Tenedos-Dardanelles . | | Due to ship's anchor. |
| 10 | | | | Malta-Alexandria . . | | — |
| 11 | | 24 | | Emden-Vigo . . . . (see 'Electrician,' April 2, 1897) | 23 | 4h. 19m. 12s. P.M. |
| 12 | IV. | 14 | | Benguela-Mossamedes | | — |
| 13 | | 19 | 6 30 P.M. | Chio-Syra . . . . . | 17 | 10h. 43m. P.M. ? |
| 14 | | 20 | 3 0 P.M. | Hong Kong-Macao . | 19 | 12h. 45m. P.M. ? |
| 15 | | 25 | 10 20 A.M. | Assab-Massowah . . | | — |
| 16 | | 28 | | Konekry-Sierra Leone. | | — |
| | V. | 3 | 2 55 P.M. | Hong Kong-Macao . . | 1 | 7h. 15m. A.M. |
| | | 5 | 3 20 P.M. | Para-Maranham . . | | — |
| | | 8 | 8 40 A.M. | Perim-Assab . . . . | 8 | 1h. 52m. 30s. P.M. ? |
| | | 21 | 8 20 A.M. | Assab-Massowah . . | | — |
| | | 29 | 8 30 A.M. | Lourenço Marques-Durban . . . . } | 23<br>24 | 1h. 15m. 20s. P.M.<br>0h. 18m. 59s. A.M., 1h. 48m. 19s. A.M., & 4h. 30m. 59s. A.M. |
| | VI. | 2 | 9 25 A.M. | Grenada-Trinidad . . | 3 | 9h. 57m. 18s. A.M. ? |
| | | | | Puerto Plata - Martinique . . . . . | ,, | ,, |
| | | 24 | | Shanghai-Foochow .<br>Shanghai-Hong Kong . | { 20<br>21<br>22 | 8h. 58m. 40s. P.M.<br>8h. 14m. 43s. P.M.<br>2h. 11m. 40s. P.M. |
| | | 25 | 5 45 A.M. | Bonny-Cameroon . . | 24 | 7h. 34m. 53s. P.M. |

*APPROXIMATE TIME OF CABLE FAILURES—continued.*

| No. | Approximate | | | Name of Cable | Exact Time of Earthquake | |
|---|---|---|---|---|---|---|
| | Month | Day | Time | | Day | Hour, G.M.T. & Remarks |
| | VII. | 4 | 8 20 A.M. | Emden-Vigo . . . . | | |
| | | 13 | | Zanzibar-Mombassa . | | — |
| | | 15 | 5 50 P.M. | Accrâ-Kotonou * (or Porto Novo) . . | | Shock at Laibach. Not recorded at Shide. |
| | | 19 | 2 35 P.M. | Cape Town - Mossamedes . . . . . | 17 | 7h. 57m. 9s. A.M. |
| | | 21 | | Cayenne-Para . . . | 21<br>22 | 1h.33m.32s. P.M. Large.<br>11h. 20m. A.M. Moderate. |
| | | 23 | 8 20 A.M. | Chypre-Lattique. . . | ,, | ,, |
| | | 28 | 8 10 A.M. | Aden-Zanzibar . . . | | — |
| | VIII. | 7 | 2 30 P.M. | Cape Town - Mossamedes . . . . | 5 | 0h. 22m. 35s. A.M. |
| | | | | Syra-Chio . . . . . | ,, | ,, |
| | IX. | 1 or 2 | | St. Vincent-St. Jago . | 1 | 6h.29m.41s. P.M. Small. |
| | | 4 | 4 10 P.M. | Mozambique-Lourenço Marques . . . . | 5 | 1h. 21m. 59s. P.M. ? Small, but long. |
| | | 13 | 3 30 P.M. | Boulama-Bissao . . | 12 | 10h. 54m. 18s. P.M. Small. |
| | | 28 | 2 30 | Hong Kong-Macao . . | 25 | 6h. 3m. 39s. P.M. Small. |
| | | 29 | | Cayenne-Pinheiro . . | | |
| | X. | 5 | 3 10 P.M. | Zanzibar-Seychelles . | 2<br>3 | 1h. 36m. 39s. P.M.<br>3h. 7m. 9s. P.M. |
| | | 11 | 2 35 P.M. | Otranto-Vallona . . | | — |
| | | 18 | 2 20 P.M. | Mozambique-Lourenço Marques . . . . | 19 | 0h. 6m. 52s. A.M. Large. |
| | | 23 | 3 20 P.M. | Amazon beyond Santa Vem . . . . . | 20 | 2h.43m.59s. P.M. Large. |
| | | 25 | 5 30 P.M. | Paramaribo-Cayenne . | 23 | 3h. 19m. 0s. A.M. & 5h. 49m. 56s. P.M. |
| | | 26 | 3 20 P.M. | Cadiz-Teneriffe . . . | 23 | 3h. 19m. 0s. A.M. & 5h. 49m. 56s. P.M. |
| | | 29 | 8 45 A.M. | Santiago de Cuba-Guantanamo . . . | | — |
| | | 7 | | St. Vincent - Pernambuco . . . . . | 2<br>3 | 1h. 36m. 39s.<br>3h. 7m. 9s. |
| | | | | No. 1 Cable ('Electrician,' 29.10.97) | | |
| | XI. | 4 | 11 50 A.M. | Bundaberg-New Caledonia . . . . . | | |
| | | 8 | 2 30 P.M. | St. Thomé-Loanda . . | | |
| | | | | Cayenne-Para . . . | | |
| | | | | Amazon-Manaos . . | | |
| | | 22 | 9 0 A.M. | Ceara-Pernambuco . . | 20<br>22 | 5h. 33m. 21s. P.M.<br>9h. 48m. 45s. A.M. |
| | | 27 | 9 15 A.M. | Vigo-Borkum . . . | 25 | 10h. 1m. 48s A.M. |
| | XII. | 3 | 8 25 A.M. | San Thomé-Loanda . | | |
| | | 6 | 3 40 P.M. | Sitia-Rhodes . . . . | | |
| | | 13 | 2 25 P.M. | San Thomé-Loanda . | | |
| | | 20 | 4 10 | Saigon, Thunaut Cable | 17 | 6h. 30m. P.M. |
| | | 23 | 5 40 P.M. | Ceara-Maranham . . | | |
| | | 29 | 9 40 A.M. | Grenada-Trinidad . . | 28 | 8h. 54m. 21s. P.M. |
| | | 31 | 4 20 P.M. | CapeHaytien, Puerto Plata, and Puerto Plata-Martinique. | 29 | 11h. 40m. 48s. A.M. This earthquake known cause of failure. |

APPROXIMATE TIME OF CABLE FAILURES—*continued.*

| No. | Approximate | | | Name of Cable | Exact Time of Earthquake | |
|---|---|---|---|---|---|---|
| | Month | Day | Time | | Day | Hour, G.M.T. & Remarks |
| | | | | **1898.** | | |
| | I. | 3 | 8 50 A.M. | Para-Maranham | 3 | 2h. 41m. 2s. P.M. & 3h. 7m. 15s. P.M. |
| | | 5 | 6 5 P.M. | Curaçao-La Guayra | | |
| | | 6 | 9 15 A.M. | Saigon-Hong Kong | | |
| | | 13 | 6 0 P.M. | Para Camela Cable | | — |
| | | 23 | 10 0 A.M. | Para-Maranham | | |
| | | 26 | | Puerto Plata-C. Haiti | 24 | 11h. 45m. 49s. P.M. |
| | | 27 | 3 30 P.M. | Paramaribo-Cayenne | | — |
| | | 28 | 2 45 P.M. | Bolama-Bissao | | — |
| | II. | 7 | 8 35 A.M. | Emden-Vigo | 5<br>7 | 8h. 36m. 13s. A.M.<br>11h. 35m. 20s. P.M. |
| | | 10 | 5 55 P.M. | Lattique-Chypre | 8<br>9 | 11h. 5m. 47s. P.M.<br>10h. 57m. 36s. P.M. |
| | | 14 | 4 0 P.M. | Bolama-Bissao | 16<br>18 | 5h. 9m. 8s. P.M.<br>5h. 0m. 0s. P.M. Toronto record. |
| | | 19 | 3 45 P.M. | Bolama-Bissao | 19 | |
| | | 28 | 2 0 P.M. | Aden-Zanzibar | | Owing to repairs. |
| | III. | 6 | 2 5 P.M. | Amazon cable beyond Obidos | | |
| | | 17 | 8 45 A.M. | San Thomé-Loanda | | To effect repairs. |
| | | 19 | 8 25 A.M. | Gibraltar-Tangier | | |
| | | 19 | | Lourenço Marques-Durban | | |
| | | 24 | 8 20 A.M. | Cayenne-Pinheiro | | |
| | | 28 | 8 45 A.M. | Havre-Waterville | | |
| | | 28 | 2 40 P.M. | Odessa-Constantinople | | |
| | IV. | 4 | 5 0 P.M. | Amazon Cable beyond Gurupa | | |
| | | 9 | 3 40 P.M. | Sierra Leone-Accra | | |
| | | 14 | 8 0 P.M. | Cape Town - Mossamedes | | |
| | | 17 | 10 15 A.M. | Maranham-Para | | |
| | | 20 | 2 30 P.M. | Benguela-Mossamedes | | |

* Kotanu; is also called Porto Novo sometimes. (Kotanu is on the *coast*, Porto Novo, a few miles *inland*.)

† Thunau, also called Hué.

The earthquake records are not continued beyond February 19, 1898.

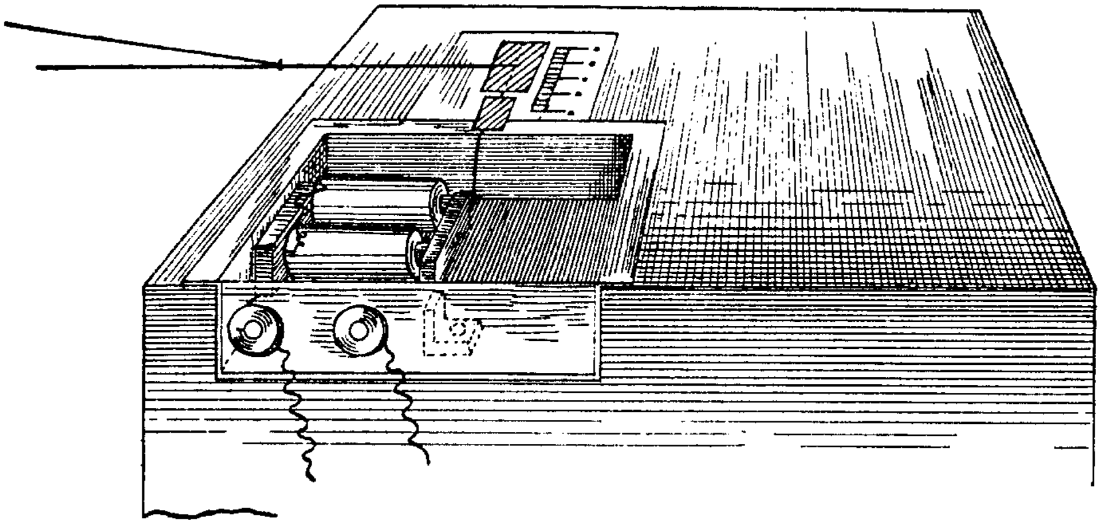
The three breaks which took place in November and December, 1897, on the San Thomé-Loanda line did so at the same place about 150 miles off the north of the Congo, where there is a depth of some 1,300 fathoms.

Mr. R. Kaye Gray points out that here we have a river bed extending seawards as a deep gulley the walls of which are 2,000 feet in height. In 1,550 fathoms a strong under-current renders it difficult to obtain soundings. In the mouth of the Congo there is a depth of only ten fathoms, and it does not seem likely that the rivers flowing over this shallow would dive down to produce the under-tow observed at a distance of 150 miles off the coast. Mr. Gray's idea is that we have here a case of subterranean water bursting out in the bed of the ocean, moving heavy detritus across the cable to cause interruption, whilst lighter particles rise to the surface to discolour the ocean. There is no evidence suggesting that these failures were any way connected with seismic phenomena.

## VIII. *A Time Indicator.*

A slight modification in the method of obtaining time marks on the photographic film connected with the Milne Horizontal Pendulum is shown in the accompanying sketch :—

FIG. 9.



The watch, with its eclipse hand (see Report, 1897, p. 138), is replaced by a small electromagnet which every hour, by a current lasting about 20 seconds, holds an eclipse plate over one end of the slit in the lid of the box containing the clock driving the bromide film. The two wires connect with two brass studs in the lower edge of the upper part of the film-box, which fit into brass sockets in the upper edge of the lower half of the same box. From these sockets wires connect with the wheels on the two sides of the box, the rails on which these run leading to a clock giving the required length of contact.

To get this length of contact the Shide arrangement is to prolong the minute hand of a regulator with about $\frac{1}{4}$ inch of platinum wire, which every hour passes through a globule of mercury about the size of a pea, standing *up* in a small insulated iron cup fitted in the brass frame which carries the glass covering the clock face. The only advantage of this arrangement is that it saves a little time in winding and comparing the watch. Two platinum contacts rather than a platinum mercury contact would be preferable.

## IX. *On the Civil Time employed throughout the World.*

With the kind assistance of the Foreign Office, the Colonial Office, and the India Office, copies of the following letter have been circulated throughout the world. The text of the circular explains the object in view. Numerous replies have been received from our Colonies, India and its dependencies, but until these have been supplemented by replies from many foreign countries the general report which it is desired to draw up cannot be made. It is hoped that the necessary tabulation may be undertaken for the Report for 1899.

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE:
Burlington House,
London, W.

SIR,—It is, I think, remarkable that there appears to be no publication which shows the corresponding value in Greenwich mean time of the local time employed throughout the world.

Such a table is indispensable in order to determine accurately the instant of occurrence of earthquakes, sea waves, magnetic phenomena, the despatch of telegrams, and many other events, the sequence of which in absolute time has to be determined.

Although application has been made to the Royal Observatory at Greenwich, to the Royal Geographical Society, to the Central Telegraph Office in London, to the offices of cable companies, and to other possible sources of information, very little has been obtained.

As a Secretary of the British Association Committee whose names are appended, I desire to publish in their forthcoming Report a table showing the differences between Greenwich mean time as used in England and Scotland and that of the civil times used in various parts of the world.

By civil time I mean the time used by railways, telegraphs, and for ordinary public affairs.

If different times are used in various parts of your country, I trust that you will be able to give information relating to the same.

Feeling assured of the value of the table it is intended to compile, I sincerely trust that you will favour me with a full and explicit statement of the time generally employed in your country. If it is mean time, state the meridian; the observatory, or the place to which this refers; and also, as a check against any misunderstanding, please state distinctly the equivalent of December 1, 9 A.M. G.M.T. in the local time, or times adopted in your own country.

I have the honour to remain, Sir,
Your obedient servant,
JOHN MILNE.

## X. *Great Circle Distances and Chords of the Earth.*[1]

The highest velocity which can be calculated for the transmission of an earthquake wave is that which is determined when we assume that its path from its origin to an observing station has followed a great circle over the surface of the earth, whilst a lower velocity is obtained on the hypothesis that the movement has passed along a chord through the earth.

Inasmuch as an earthquake origin, especially if submarine, cannot be determined with any degree of accuracy, whilst the origin itself may have dimensions measured by several tens of miles, a simple and sufficiently accurate method of determining great circle distances is to measure the same with a flat steel tape or a piece of thread upon the surface of a globe.

[1] A table giving the lengths in kilomètres of arcs and chords of the earth has been drawn up by Mr. James Arnott, and the same may be had on application to Mr. J. Milne, a secretary of this committee.

### XI. *Tables of Certain Small Fractions of an Hour.*

The film used with the Milne Horizontal Pendulum is supposed to be driven at the rate of 60 mm. per hour. In consequence of changes in temperature, varying resistances in the unrolling of the film, and for other reasons, measurement between the time marks will sometimes slightly vary. The result of this is that the observer when determining the exact commencement of a disturbance finds he has to work out certain fractions of an hour. For example, he may require to know the value of $\frac{31}{59}$ of an hour, or $\frac{31}{59.75}$ of an hour, which are respectively 31 mins. 31·5 secs., and 31 mins. 07·7 sec.

Such results are shown in the following table drawn up by my assistant, Shinobu Hirota.

Inasmuch as measurements less than 0·1 mm. cannot be made on the time scale, it is evident that for all ordinary computations the decimals in the following table are not required (see British Association Report, 1896, p. 183).

| Distance from Time Mark to some Phase of a Disturbance | Intervals between Time Marks on a Film | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | MM. 58·0 per 1 hour | MM. 58·25 per 1 hour | MM. 58·50 per 1 hour | MM. 58·75 per 1 hour | MM. 59·0 per 1 hour | MM. 59·25 per 1 hour | MM. 59·50 per 1 hour | MM. 59·75 per 1 hour | MM. 60·0 per 1 hour |
| MM. | M. S. | M. S. | M. S. | M. S. | M. S. | M. S. | M. S. | M. S. | M. S. |
| 0·25 | 0 15·51 | 0 15·45 | 0 15·38 | 0 15·31 | 0 15·25 | 0 15·19 | 0 15·12 | 0 15·06 | 0 15 |
| 0·50 | 0 31·03 | 0 30·90 | 0 30·77 | 0 30·63 | 0 30·5[illegible] | 0 30·38 | 0 30·25 | 0 30·12 | 0 30 |
| 0·75 | 0 46·55 | 0 46·35 | 0 46·15 | 0 45·95 | 0 45·75 | 0 45·57 | 0 45·37 | 0 45·18 | 0 45 |
| 1 | 1 02·07 | 1 01·80 | 1 01·53 | 1 01·27 | 1 01·01 | 1 00·76 | 1 00·50 | 1 00·25 | 1 0 |
| 2 | 2 04·14 | 2 03·60 | 2 03·07 | 2 02·55 | 2 02·03 | 2 01·51 | 2 01·00 | 2 00·50 | 2 0 |
| 3 | 3 06·20 | 3 05·41 | 3 04·61 | 3 03·83 | 3 03·05 | 3 02·27 | 3 01·50 | 3 00·75 | 3 0 |
| 4 | 4 08·27 | 4 07·21 | 4 06·15 | 4 05·10 | 4 04·06 | 4 03·03 | 4 02·01 | 4 01·00 | 4 0 |
| 5 | 5 10·34 | 5 09·01 | 5 07·69 | 5 06·38 | 5 05·08 | 5 03·79 | 5 02·52 | 5 01·25 | 5 0 |
| 6 | 6 12·41 | 6 10·81 | 6 09·23 | 6 07·66 | 6 06·10 | 6 04·55 | 6 03·02 | 6 01·50 | 6 0 |
| 7 | 7 14·48 | 7 12·61 | 7 10·77 | 7 08·93 | 7 07·11 | 7 05·31 | 7 03·52 | 7 01·75 | 7 0 |
| 8 | 8 16·55 | 8 14·42 | 8 12·31 | 8 10·21 | 8 08·13 | 8 06·07 | 8 04·03 | 8 02·01 | 8 0 |
| 9 | 9 18·62 | 9 16·22 | 9 13·84 | 9 11·49 | 9 09·15 | 9 06·83 | 9 04·53 | 9 02·26 | 9 0 |
| 10 | 10 20·69 | 10 18·02 | 10 15·38 | 10 12·76 | 10 10·16 | 10 07·59 | 10 05·04 | 10 02·51 | 10 0 |
| 11 | 11 22·76 | 11 19·82 | 11 16·92 | 11 14·04 | 11 11·18 | 11 08·35 | 11 05·54 | 11 02·76 | 11 0 |
| 12 | 12 24·83 | 12 21·63 | 12 18·46 | 12 15·31 | 12 12·20 | 12 09·11 | 12 06·05 | 12 03·01 | 12 0 |
| 13 | 13 26·90 | 13 23·43 | 13 20·00 | 13 16·59 | 13 13·22 | 13 09·87 | 13 06·55 | 13 03·26 | 13 0 |
| 14 | 14 28·96 | 14 25·23 | 14 21·53 | 14 17·87 | 14 14·23 | 14 10·63 | 14 07·05 | 14 03·51 | 14 0 |
| 15 | 15 31·03 | 15 27·03 | 15 23·07 | 15 19·16 | 15 15·25 | 15 11·39 | 15 07·56 | 15 03·76 | 15 0 |
| 16 | 16 33·10 | 16 28·84 | 16 24·61 | 16 20·42 | 16 16·27 | 16 12·15 | 16 08·06 | 16 04·01 | 16 0 |
| 17 | 17 35·17 | 17 30·64 | 17 26·15 | 17 21·70 | 17 17·28 | 17 12·91 | 17 08·57 | 17 04·26 | 17 0 |
| 18 | 18 37·24 | 18 32·44 | 18 27·69 | 18 22·97 | 18 18·30 | 18 13·67 | 18 09·07 | 18 04·51 | 18 0 |
| 19 | 19 39·31 | 19 34·25 | 19 29·23 | 19 24·25 | 19 19·32 | 19 14·43 | 19 09·58 | 19 04·77 | 19 0 |
| 20 | 20 41·38 | 20 36·05 | 20 30·77 | 20 25·53 | 20 20·33 | 20 15·19 | 20 10·08 | 20 05·02 | 20 0 |
| 21 | 21 43·45 | 21 37·85 | 21 32·31 | 21 26·80 | 21 21·35 | 21 15·95 | 21 10·58 | 21 05·27 | 21 0 |
| 22 | 22 45·51 | 22 39·65 | 22 33·84 | 22 28·08 | 22 22·37 | 22 16·70 | 22 11·09 | 22 05·52 | 22 0 |
| 23 | 23 47·58 | 23 41·46 | 23 35·38 | 23 29·36 | 23 23·39 | 23 17·46 | 23 11·59 | 23 05·77 | 23 0 |
| 24 | 24 49·65 | 24 43·26 | 24 36·92 | 24 30·63 | 24 24·40 | 24 18·22 | 24 12·10 | 24 06·02 | 24 0 |
| 25 | 25 51·72 | 25 45·06 | 25 38·46 | 25 31·91 | 25 25·42 | 25 18·98 | 25 12·60 | 25 06·27 | 25 0 |
| 26 | 26 53·79 | 26 46·86 | 26 40·00 | 26 33·19 | 26 26·44 | 26 19·74 | 26 13·11 | 26 06·52 | 26 0 |
| 27 | 27 55·86 | 27 48·67 | 27 41·53 | 27 34·46 | 27 27·45 | 27 20·50 | 27 13·61 | 27 06·77 | 27 0 |
| 28 | 28 57·93 | 28 50·47 | 28 43·07 | 28 35·74 | 28 28·47 | 28 21·26 | 28 14·11 | 28 07·03 | 28 0 |
| 29 | 30 00·00 | 29 52·27 | 29 44·61 | 29 37·02 | 29 29·49 | 29 22·02 | 29 14·62 | 29 07·28 | 29 0 |
| 30 | 31 02·07 | 30 54·07 | 30 46·15 | 30 38·29 | 30 30·50 | 30 22·78 | 30 15·12 | 30 07·53 | 30 0 |
| 31 | 32 04·14 | 31 55·88 | 31 47·69 | 31 39·57 | 31 31·52 | 31 23·54 | 31 15·63 | 31 07·78 | 31 0 |
| 32 | 33 06·20 | 32 57·68 | 32 49·23 | 32 40·85 | 32 32·54 | 32 24·30 | 32 16·13 | 32 08·03 | 32 0 |
| 33 | 34 08·27 | 33 59·48 | 33 50·77 | 33 42·12 | 33 33·55 | 33 25·06 | 33 16·64 | 33 08·28 | 33 0 |
| 34 | 35 10·34 | 35 01·28 | 34 52·31 | 34 43·40 | 34 34·57 | 34 25·82 | 34 17·14 | 34 08·53 | 34 0 |
| 35 | 36 12·41 | 36 03·09 | 35 53·84 | 35 44·68 | 35 35·59 | 35 26·58 | 35 17·65 | 35 08·78 | 35 0 |
| 36 | 37 14·48 | 37 04·89 | 36 55·38 | 36 45·95 | 36 36·60 | 36 27·34 | 36 18·15 | 36 09·03 | 36 0 |
| 37 | 38 16·55 | 38 06·69 | 37 56·92 | 37 47·23 | 37 37·62 | 37 28·10 | 37 18·65 | 37 09·29 | 37 0 |
| 38 | 39 18·62 | 39 08·49 | 38 58·46 | 38 48·51 | 38 38·64 | 38 28·86 | 38 19·15 | 38 09·54 | 38 0 |
| 39 | 40 20·69 | 40 10·30 | 40 00·00 | 39 49·78 | 39 39·66 | 39 29·62 | 39 19·66 | 39 09·79 | 39 0 |
| 40 | 41 22·76 | 41 12·10 | 41 01·53 | 40 51·06 | 40 40·67 | 40 30·38 | 40 20·16 | 40 10·04 | 40 0 |
| 41 | 42 24·83 | 42 13·90 | 42 03·07 | 41 52·34 | 41 41·69 | 41 31·14 | 41 20·67 | 41 10·29 | 41 0 |
| 42 | 43 26·90 | 43 15·71 | 43 04·61 | 42 53·61 | 42 42·71 | 42 31·90 | 42 21·17 | 42 10·54 | 42 0 |
| 43 | 44 28·97 | 44 17·51 | 44 06·15 | 43 51·89 | 43 43·72 | 43 32·66 | 43 21·67 | 43 10·79 | 43 0 |
| 44 | 45 31·03 | 45 19·31 | 45 07·67 | 41 56·17 | 44 44·74 | 44 33·42 | 44 22·18 | 41 11·04 | 44 0 |

| Distance from Time Mark to some Phase of a Disturbance | Intervals between Time Marks on a Film | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | MM. 58·0 per 1 hour | MM. 58·25 per 1 hour | MM. 58·50 per 1 hour | MM. 58·75 per 1 hour | MM. 59·0 per 1 hour | MM. 59·25 per 1 hour | MM. 59·50 per 1 hour | MM. 59·75 per 1 hour | MM. 60·0 per 1 hour |
| MM. | M. S. | M. S. | M. S. | M. S. | M. S. | M. S. | M. S. | M. S. | M. S. |
| 45 | 46 33·10 | 46 21·11 | 46 09·23 | 45 57·44 | 45 45·76 | 45 34·18 | 45 22·68 | 45 11·29 | 45 0 |
| 46 | 47 35·17 | 47 22·92 | 47 10·77 | 46 58·72 | 46 46·78 | 46 34·94 | 46 23·19 | 46 11·54 | 46 0 |
| 47 | 48 37·21 | 48 24·72 | 48 12·31 | 48 00·00 | 47 47·79 | 47 35·70 | 47 23·69 | 47 11·79 | 47 0 |
| 48 | 49 39·31 | 49 26·52 | 49 13·84 | 49 01·27 | 48 48·81 | 48 36·45 | 48 24·20 | 48 12·05 | 48 0 |
| 49 | 50 41·38 | 50 28·32 | 50 15·38 | 50 02·55 | 49 49·82 | 49 37·21 | 49 24·70 | 49 12·30 | 49 0 |
| 50 | 51 43·15 | 51 30·13 | 51 16·92 | 51 03·83 | 50 50·84 | 50 37·97 | 50 25·21 | 50 12·55 | 50 0 |
| 51 | 52 45·51 | 52 31·93 | 52 18·46 | 52 05·10 | 51 51·86 | 51 38·73 | 51 25·71 | 51 12·80 | 51 0 |
| 52 | 53 47·58 | 53 33·73 | 53 20·00 | 53 06·38 | 52 52·88 | 52 39·49 | 52 26·22 | 52 13·05 | 52 0 |
| 53 | 54 49·65 | 54 35·53 | 54 21·53 | 54 07·66 | 53 53·89 | 53 40·25 | 53 26·72 | 53 13·30 | 53 0 |
| 54 | 55 51·72 | 55 37·34 | 55 23·07 | 55 08·93 | 54 54·91 | 54 41·01 | 54 27·22 | 54 13·55 | 54 0 |
| 55 | 56 53·79 | 56 39·14 | 56 24·61 | 56 10·21 | 55 55·93 | 55 41·77 | 55 27·73 | 55 13·80 | 55 0 |
| 56 | 57 55·86 | 57 40·94 | 57 26·15 | 57 11·49 | 56 56·94 | 56 42·53 | 56 28·23 | 56 14·06 | 56 0 |
| 57 | 58 57·93 | 58 42·74 | 58 27·69 | 58 12·76 | 57 57·96 | 57 43·29 | 57 28·74 | 57 14·31 | 57 0 |
| 58 | 60 00·00 | 59 44·55 | 59 29·23 | 59 14·04 | 58 58·98 | 58 44·05 | 58 29·24 | 58 14·56 | 58 0 |
| 58·25 | — | 60 00·00 | 60 00·00 | — | — | — | — | — | 58 15 |
| 58·50 | — | — | — | — | — | — | — | — | 58 30 |
| 58·75 | — | — | — | 60 00·00 | — | — | — | — | 58 45 |
| 59·00 | — | — | — | — | 60 00·00 | 59 44·81 | 59 29·75 | 59 14·81 | 59 0 |
| 59·25 | — | — | — | — | — | 60 00·00 | — | — | 59 15 |
| 59·50 | — | — | — | — | — | — | 60 00·00 | — | 59 30 |
| 59·75 | — | — | — | — | — | — | — | 60 00·00 | 59 45 |
| 60 | — | — | — | — | — | — | — | — | 60 00 |

## XII. *Notes on a Visit to Earthquake Observatories in Italy and at Strassburg. By* John Milne.

With the object of more clearly understanding the nature of certain forms of seismographic apparatus referred to or described in various publications, to see instruments and experimental apparatus descriptions of which have yet to be published, to learn something respecting their various degrees of sensibility and their installation, to see the manner in which they are manipulated—which in many instances it is difficult to express in words—and, above all, to make myself acquainted with certain European organisations for the study of movements of the earth's crust, in May of this year I visited seismological observatories and offices at Catania, Cassamicciola, Rome, Rocca di Papa, Padua, and Strassburg.

At these particular stations there exist types of all the most important seismometers, seismographs, and seismoscopes which are at present employed in Europe, and it was for that reason that they were visited.

In the following few notes it is not my intention to describe all that I saw—inasmuch as that would be a repetition of much that is published—but only to say a few words respecting that which was striking and to record general impressions.

Catania.—*Gli Osservatorii di Catania e dell'Etna. Director,* Professor A. Ricco.

For a detailed description of these observatories see 'Memorie della Società degli Spettroscopisti Italiani,' vol. xxvi. 1897.

In 1669 a great part of Catania was destroyed, and 27,000 lives were lost, by an eruption from one of the many parasitic craters which flank the mound-like mass which with its central peak constitutes Etna. One feature of the eruption was a flow of lava which passed over and through the city, and only stopped when it entered the sea. This stream is now patched over with yellow lichen, and along the sides of the railway which passes through it as it enters the city from the north many cuttings in rock and scoria give a good idea of the character of the materials on which Catania and its observatory are founded.

The observatory, which overlooks the city and the sea, stands on the top of one of the steps indicating the contour of the country now buried by the molten flood of 1669.

The buildings are rugged, large, and massive, and apparently form portion of an uncompleted church; and it is in the spacious vaults of this church (Convento dei Benedettini) beneath the astrophysical observatory that the Seismological Laboratory is established.

The foundations of these buildings, like those of many of the buildings in Catania, follow the very irregular contour of the lava bed from which they rise.

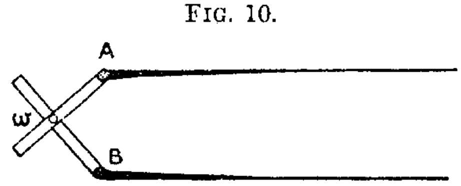
*The Instruments.*

The entrance to the Physical Observatory on the north side is a hall at the end of which stone stairs lead to upper storeys. In the open space between these there is a thin metal tube reaching from the roof above, and passing downwards through the floor into the vaults beneath. This tube, which is steadied by horizontal wire ties, protects the supporting wire of the great pendulum, which is about 25·3 metres (83 feet) in length. At its upper end it is supported from a double T-iron beam, and at its lower end it carries a cylindrical mass of metal weighing 300 kilos. The bob hangs freely in a case standing on the floor of a special chamber in the crypt-like vaults below.

The movements of the pendulum or of the ground relatively to the same are recorded by pens charged with glycerine ink, somewhat similar to the pens employed in the Richard meteorological instruments, upon a band of paper moving at a rate of one cm. per minute. These pens, which are balanced so that they barely touch the recording surface, are attached to the ends of aluminium levers which multiply the relative motion of the pendulum and the ground 12·5 times. The shorter arms of these levers (A C and B C) are slotted, and embrace the wire of the pendulum, which is 6 mm. thick, just above the bob (fig. 10).

The motion is recorded by suitable levers. At each hour, by means of an electro-magnet in connection with a chronograph, the pens are gently raised from the paper for a period of about six seconds. In this manner time intervals are obtained.

FIG. 10.




Inasmuch as the period of the pendulum relatively to that of local earthquakes is long, it acts as a steady point, and a record of the movements of the ground magnified about 12·5 times is obtained upon the moving band of paper. Two such shocks were recorded on the morning of my arrival in Catania.

With the long-period earthquakes originating at great distances it is assumed that the pendulum follows the slowly tilting ground.

S 2

If this is the case, then 1 mm. deflection of the writing indices corresponds to 0·6 sec. of arc.

When the pendulum has given to it a swing with a range of motion as shown by the writing indices of 3·5 cm. after nine complete swings, it comes to rest in 1 min. 42 secs.

The shortness of this interval indicates that in the recording apparatus, especially perhaps with the pens, there is considerable frictional resistance; a feature in the apparatus which I understood Professor Ricco has the intention of improving.

High winds and waves beating on the coast result in a tremulous movement of the writing indices, so that if an earthquake occurred at such a time I presume the rapid movements at its commencement might be eclipsed.

In the centre of a spacious chamber adjoining that in which the large pendulum is installed there is a massive column in the form of a truncated cone, the greatest visible diameter of which is 5 metres. It rises from the floor in the form of a solid circular wall, to the centre of the annular space which this incloses there is an opening. Instruments standing on this can be examined either by walking round the outside or round the inside of this horseshoe-formed pedestal.

At the time of my visit there were standing upon it eight or ten seismoscopes, the microseismoscope of Guzzanti and the seismograph of Brassart.

Amongst the seismoscopes I noted a light spiral spring carrying a weight with a style: if this moved slightly downwards—say less than 5 mm.—it came in contact with a surface of mercury and closed an electric circuit the time of which might be noted in various manners. The essential feature in two other seismoscopes was a small column standing upon an exceedingly small base. In one instance the column stands freely. To place the column in such a position directly by hand would for many people be almost an impossibility. It is therefore suspended by a collar to hang freely in a tube. When the tube is lowered between guides the bottom of the column comes down upon its base and it remains standing upright.

In another instance the column is brought to a practically upright position by leaning it against a support which by means of a screw is gradually advanced until the column is on the verge of falling. In both cases the columns are in an extremely unstable condition, and, should they fall either by their weight or by making an electric contact, they start a clock or actuate other apparatus which gives the times at which they were disturbed.

The apparatus employed to yield open diagrams of local shocks is a Brassart seismograph. This consists of a pendulum, 3 metres in length, carrying as a bob a ring of metal weighing 26·4 kilos. Embracing a style which projects from the bob downwards are two levers arranged as in the large seismograph. These multiply motion relatively to the pendulum ten times, and their outer ends rest side by side on the surface of smoked glass plate which at the time of an earthquake is set free by electric contact from one of the seismoscopes to run at a rate of about 445 mm. per minute.

The vertical component of motion is obtained either by making a portion of the suspension of the pendulum a spiral spring and treating the heavy bob of the pendulum as a steady point, or from a spring lever seismograph attached to the frame carrying the ordinary pendulum. By a system of levers from the bob of the latter, or from the weighted extremity of the spring lever, a third pointer writes the vertical component of motion side by side with the horizontal components.

I particularly wish to draw attention to this type of instrument, because I found it at several observatories, and it is a type that has evidently found favour in the *Italian* Peninsula.

For disturbances of short period it has no doubt been found effective, but for the long rolling movements produced by earthquakes originating at distances of 100 or 200 kilometres, when we have periods of from one to four seconds, my own experience is that with such pendulums a more or less violent swinging is established.

The microseismoscope of Guzzanti consists of three inverted pendulums of different periods arranged to make electric contacts. Should they be set in a state of vibration, these contacts are recorded by an electric magnet actuating a pen upon a moving band of paper.

The Cecchi seismograph at Catania, as at other stations I visited, was not in working adjustment, the reason for this being, I presume, that the records from a Brassart type of instrument were found more satisfactory.

Hanging against the wall of the same chamber with the large column is a Bertelli-Rossi tromometer. This consists of a pendulum several metres in length, a style from the bob or plummet of which is viewed by a microscope with a micrometer scale.

Another tromometer is that of Dr. Agamennone. This consists of an ordinary pendulum with a multiplying lever, which actuates two small mirrors, the movement of rays of light reflected from which are recorded on a moving photographic surface.

A very useful apparatus which I found here and at other observatories is the photochronograph of Dr. Cancani.

In a box attached to the wall is a chronometer, above which there is a camera containing a plate and a small electric lamp. At the time of an earthquake one or other of the seismoscopes on the great column make an electric contact, which actuating an electric magnet turns on a current for a second or so to the electric lamp. The result is that the face of the chromometer is photographed. The last piece of apparatus to which my attention was drawn was a tide gauge-like recorder for a well. The bottom of this well is, I understand, in the Pliocene strata beneath the lava on which the observatory is founded. The depth is 32 metres, and is 9·5 metres above sea level. At the time of large earthquakes the puteometric record shows that the water at that depth has been disturbed.

### *Island of Ischia*

Until this year on the island of Ischia there have been two seismological observatories—one at the town of Ischia and the other at Cassamicciola. Dr. Grablovitz, the director of these stations, told me that the former of these was to be abolished, and all the instruments brought together at Cassamicciola. From the jetty at Cassamicciola you see the observatory on the highest portion of a colline some 300 feet above sea level beneath the cliff-faced pinnacles of the extinct Epomeus. On reaching it you look down upon the newly built houses and many ruins, which testify to the disaster of 1883.

The walls of the observatory, like those of the modern buildings, instead of being built of stone and rubble, are of framed timber largely strengthened with iron straps. A few yards distant from the observatory, and in the same garden, is the residence of Dr. Grablovitz and his office.

The observatory is practically a lofty, well-lighted room 30 feet or so in diameter.

In the centre of this there is a massive horseshoe-formed column, on which stand a variety of instruments. On one of the walls is the regulator, which is from time to time corrected by noting the time when a spot of light crosses a meridian line drawn upon the floor. This takes place when the sun passes a slit in the wall in line with the mark upon the floor. Here, as at Catania, there was a three-component Brassart pendulum. Another pendulum had a length of 1 metre, and only records two components of motion, each of which is multiplied ten times.

With apparatus of this description, in which the record is received upon a drum revolving on a horizontal axis, Dr. Grablovitz arranges the pen or style so that it hangs vertically, and therefore comes in contact with the side of the recording surface instead of being, as is usually the case, upon the top of the same. Although in the latter case the pens or styles are balanced, I understood from Dr. Grablovitz that his arrangement, especially when the styles are made of a small thin strip of aluminium, is one that minimises frictional resistance. One apparatus provided with these pens was a pair of horizontal pendulums the lead weights of which were cylinders measuring about 30 cm. by 5 cm. The short arm of these pendulums was 2 cm. and the long arm 40 cm. Quick motion, due to local earthquakes, would therefore be multiplied twenty times. As I saw them they had a period of three or four seconds. If they are to be used to record earthquakes originating at a distance this quantity will be increased; but even then it is doubtful whether they will do more than record the most pronounced portion of such disturbances. This instrument, which is yet in an experimental stage, is the only one I saw whilst in Italy which approximated in its design to modern types of 'steady point' seismographs which have yielded such good results in Japan.

Side by side with these horizontal pendulums were a pair of large astronomical levels, oriented at right angles, cemented to the pier, and covered with glass cases. They are read twice daily.

The next instrument was a pair of conical pendulums, the outer extremities of the booms being so arranged that if they moved to the right or to the left they came in contact with a surface of mercury, completed an electric circuit, and set in action an alarm.

There were also other seismoscopes, but these were not in action.

My attention was next drawn to a model of an astatic suspension, which Dr. Grablovitz hopes to introduce into seismometry. This consisted of a swinging platform carrying an inverted pendulum. By raising or lowering the bob of this pendulum the period of the system is changed, the moment of the platform and that of the loaded mass acting in opposite directions.

In a room outside the main building of the observatory I saw a vasca sismica and a pair of geodynamic levels.

The vasca sismica may be described as a shallow circular tank about 1·5 metre in diameter and 1 metre in depth. Floating on the surface of the water which this contains there is a disc-formed tray nearly filling the whole tank. From two points 90° distant from each other, on the edge of this floating tray, connections are made with the short arms, each 8 mm. in length, of two light levers. The long arms of these levers are 80 cm.

in length, and therefore multiply any motion of the tray nearly 100 times. Their outer ends carry writing points, resting against the face of a drum, driven by clockwork. To prevent these pointers following the same line as the drum revolves a cylindrical sinker is gradually lowered by means of clockwork into the water. The water therefore gradually rises, and with it the floating tray, and the writing levers gradually change their position on the recording surface. The natural period of this tray when set in oscillation is about one second.

The geodynamic levels consist of two zinc tubes, each 2·5 metres in length, terminated at each end with vertical cylinders. These stand on the floor of the room at right angles to each other. On the open ends of these there are floats attached to the short arms (each 8 mm. in length) of levers. The long arm of each lever (80 cm. in length) carries a writing pointer, resting on a recording surface moved by clockwork. The natural period of these water levels is 2·5 seconds.

(For further description in English and reference to original descriptions see Report of the British Association, 1896, p. 226.)

These instruments give an exaggerated representation of the preliminary, and therefore fairly rapid, vibrations of an earthquake originating at a great distance, whilst they show but little of the succeeding slower but larger waves. The general character of their records is therefore the reverse of what is usually obtained from a horizontal pendulum.

The chief instrument at Porto d' Ischia, a few miles distant from Cassamicciola, is a pair of horizontal pendulums. The vertical height of these is 2 metres. The weights, which are 12 kilos., are carried on booms, 10 cm. in length, supported by double ties, one from each side of the weight, but coming together at a point at their attachment above the pivot of the boom. The object of this is to prevent wobbling. The boom is prolonged 80 cm. to its hanging writing point, which rests against a smoked surface of paper moving at a rate of 1 cm. per minute.

*Rome.*

The Ufficio Centrale Meteorologico e Geodinamico Italiano, which forms portion of the Collegio Romano, is a huge block of buildings surrounded by streets, which stands back about 40 yards from the Corso, one of the principal thoroughfares in Rome. The effect of the traffic is extremely slight, and only occasionally to be observed. Here I met Professor P. Tacchini, the director-in-chief of the meteorological and seismological work of Italy, who very kindly explained the general working of the departments, showed me the instruments, and indicated how I could obtain materials I might require.

One of the upper rooms is devoted to the storing of seismological records and their analysis. When an earthquake occurs in any portion of Italy the observers in the shaken district fill up a postcard-like form and forward the same to this bureau. If the shaking was confined to the island of Sicily, then some thirty of these forms would be received, whilst if it were in the peninsula some hundreds might come in.

A digest of this information, together with many detailed observations from stations provided with seismographs, is from time to time published in the 'Bollettino della Società Sismologica Italiana.' Fuller accounts of observations and instruments appear in the 'Annali dell' Ufficio Centrale Meteorologico e Geodinamico Italiano' (see vol. viii. Part IV. 1886).

Although continuous records of earth movements are made at Rome, the chief work beyond the compilation of the official records is that of testing and experimenting with new forms of apparatus.

The continuous recorders are three pendulums. The larger of these, which is 16 metres in length, and carries a mass of 200 kilos. relatively, to which motion is magnified twelve times, had, I understood, gone to the exhibition in Turin. One which I saw, and known as the Seismometografo Medio, is 8 metres in length, and carries a mass of 100 kilos., with pointers magnifying ten times. These pointers are pens carrying an ink containing much glycerine.

In general form they are like the pens used on the Richard meteorological instruments, but there is some difference in their construction.

They rest upon a band of paper usually moving at a rate of 30 cm. per hour, but at the time of an earthquake, for a period of $1\frac{1}{2}$ minute, this speed is increased to 120 cm. per hour, and until the earthquake ceases this speed is continued.

When the pendulum is caused to swing, so that the writing indices have a range of 2·5 cm., it comes to rest after ten complete oscillations within a period of 11 minutes. The period therefore is a little over one minute; that is to say, a pendulum with a free period of hardly six seconds is increased to more than sixty seconds in consequence of the damping action of writing indices (?).

This apparatus, together with other instruments, is in the basement of the building, and I understood, like that at Catania, indicates tremors due to wind and occasionally the effects of traffic.

Near to it is a Brassart three-component seismograph, 1·5 metre long, carrying 10 kilos., and multiplying motion ten times.

There were also three seismoscopes: one consisted of a light spiral spring, carrying a weight from which depended a second spiral with a weight, the style of the latter being at rest just above a surface of mercury.

A second seismoscope was a pendulum the style of which hung freely in a small hole in a brass plate. By a slight movement the style comes in contact with the plate, when an electric circuit is completed.

The third seismoscope, designed by Dr. Agamennone, was the most sensitive. It consists of two inverted pendulums having different periods. The upper end of the quicker of the two passes through but without touching the sides of a small hole in a metal plate carried on the slower vibrator. A movement of either results in contact, when an electric circuit actuating a magnet releases the record-receiving surface of a Brassart seismograph, or by some other means records the fact that there has been movement.

### *Rocca di Papa.*

I left Rome to visit Rocca di Papa in company with Dr. A. Cancani, the director of the observatory at that place, and the veteran seismologist Professor M. S. di Rossi. As far as Frascati we travelled by rail, after which came a drive of $1\frac{1}{2}$ hour, when we found ourselves opposite the Albergo Angelletto in Rocca di Papa, some fifteen or twenty miles S.E. from Rome, looking down upon the Campagna. From this point there is yet a steep climb, up streets and lanes through the garden of Professor Rossi, past the caves in which he made his historical tromometrical researches, and then by a zigzag pathway through a wood before the observatory is reached.

At the doorway you stand 760 metres above sea level on a boss of leucite basalt, the nucleus of a once extensive crater. Looking down, you see the roofs and gardens of Rocca di Papa beneath, towards the left is the crater lake of Albano, and towards the right the villages and towns which dot the Campagna, Rome with its St. Peter's, domes and towers, and in the far distance the Mediterranean. There is nothing above you, and you see homesteads and hamlets, with here and there a town below as in a plan.

The first thing to be noticed is that the observatory, although built of stone, is covered with galvanised iron sheets. The object of this is to prevent the absorption of moisture, which in consequence of mist and an annual rainfall, which at this elevation exceeds one metre, would be excessive.

An ascent up a few steps takes the visitor through glass doors, which are opened by a custodian in official uniform, into a lofty, well-lighted octagonally-shaped room about 8 metres in width. From the basement a column of masonry 6 metres in diameter rises up to the floor of this room, where it is continued upwards into the room itself as an annular table about 3 feet in width and 3 feet in height. This, which is faced and covered with white marble, carries about twelve instruments.

In the centre of the annular space a circular column 1·25 metre in diameter rises nearly to the roof of the building. I understood that the object of this was to study the behaviour of certain instruments placed near its top as compared with that of similar instruments placed at lower levels.

At the time of my visit five seismoscopes were installed on small shelves attached round the summit of this shaft. These are electrically connected with a Brassart seismograph, and when one or any of them are agitated the recording surface connected with this apparatus is set in motion. Experience shows that seismoscopes installed upon the top of this elastic column move sooner than similar apparatus placed upon the circular desk.

Hanging round the sides of the column are a series of tromometers, varying in length from about 15 feet to 6 inches (see description of the Catania tromometer). At the present time I believe it is only the longest and shortest of these which are observed, records being taken five times daily.

On the circular table there are a large number of seismoscopes, including the original designs of Professor M. S. di Rossi,[1] Brassart's Seismograph and the Photo Chronograph of Dr. Cancani.

At this observatory there is another example of the long pendulums. It is 15 metres in length and carries 250 kilos. The multiplication is, as at Catania, 12·5 times, and the record is with ink. On the opposite side of the room and hanging from the wall is a Vicentini pendulum, which will be described with the instruments I saw at Padua.

Among the most striking pieces of apparatus at this observatory are a pair of horizontal pendulums constructed by Dr. Cancani, which of their kind are the largest in existence. The height of the vertical axis is 5·25 metres (17 ft.), and the length of the horizontal boom is 2·7 metres (8 ft. 9 in.). Each pendulum is constructed from two pieces of T-iron brought together and joined to form two sides of a triangle. The free

[1] See *La Meteorologia Endogena*, vol. ii.

ends of the base, which if joined would form the base of the triangle, are provided with pivots which bear in steel cups.

The plane of the triangular frame is placed parallel to a wall, and its upper pivot hooks into the upper cup, whilst the lower pivot bears directly into the cup near the floor, which has a lateral and fore-and-aft adjustment. On the apex of the swinging triangle a weight of about 25 kilos. is placed. In one case this was pig-iron and in the other a block of marble. Projecting from each apex is a film of glass resting on a drum moving a band of smoked paper at a rate of 60 cm. per hour. At each hour by electrical connections with a chronometer the pointers are lifted for a short interval of time from the recording surface, and time marks are obtained.

At first these pendulums carried pens writing on paper, and it is instructive to notice the great difference in the frictional resistance of these and the ends of rounded glass fibre on smoked paper.

After a deflection of 3 cm. the ink pen continues to move for 12 minutes with a period of 22 seconds, but after a similar deflection with the fibre resting on smoked paper the movement continues for more than one hour, the period being nearly the same.

This apparatus has yielded several instructive diagrams of earthquakes, the most striking of which is that of the Assam earthquake of June 1897.

Whilst examining the seismoscopes Dr. Cancani sketched one of his own, which he considered extremely sensitive. It consists of six inverted elastic pendulums arranged to stand round the circumference of a small circle. Each of these is a vertically placed steel wire the upper end of which is a spiral terminating with a style. These styles are adjusted in close juxtaposition with the edges of a metal disc with which, if they should vibrate, they come in contact. Each of these wires is loaded, but at different heights from their base, with a metal ball, and therefore they have different periods of motion. Contact with the disc completes an electric circuit.

In the Cecchi seismoscope a small column stands freely on a horizontal plate fixed on the top of the style of an inverted pendulum similar to that just described. When this falls, because it is attached by a thread to a catch-controlling clockwork, this catch is released, and the clockwork set in motion.

*Padua.*

Although the time spent at Padua was, I regret to say, extremely short, in consequence of the kindness of Professor Vicentini and his assistant Dr. Pacher, who had arranged seismograms and apparatus for my inspection, much was learned during the visit. The instruments which are of the heavy pendulum type, are established on the walls of one of the physical laboratories of the University Buildings, which are surrounded by the traffic of the city. Considering the position in which they are placed on an upper storey, which, as Professor Vicentini remarked was only occupied from necessity, it is remarkable that so many new and valuable results have been obtained. Although the walls of the University, like most old buildings in Italy, are remarkably solid, they rise from an alluvium foundation, which is very elastic. One result of this is that the movements of the soil due to passing traffic, the ringing of a bell at no great distance, and the pulsations of the ground apparently accompanying fluctuations in barometric pressure at the time of a storm in the distant Alps are all recorded.

Two pendulums which hang side by side had lengths of 1·50 metre, and carried weights of 100 kilos. Side by side with one of these was a bar of steel, about 1·5 metre in length and 10 cm. broad, firmly fixed at one end and bent downwards at the other by a load of 45 kilos. The object of this is to record vertical motion.

The full period of this loaded spring is 1·1 sec. Its outer end is connected by a system of levers with a writing point which rests on a surface of smoked paper side by side with the writing indices of horizontal motion connected with the ordinary pendulum. (For a short description of the ordinary pendulum see *British Association Report*, 1896, p. 221. For a complete description see 'I Microsismografi dell' Instituto di Fisica della R. Università di Padova:' Dr. Giulio Pacher. *Atti del R. Instituto Veneto di Scienze, Lettre ed Arti*, tomo viii. serie vii. 1896–97).

In another room there is a similar pendulum, which is, however, 11 metres in length and carries a much heavier load (400 kilos.). In addition to the two systems of levers for horizontal motion, projecting from the bottom of the pendulum is a light pantograph, which gives a resultant motion. The diagram from this latter arrangement is one from which the direction of various vibrations can be easily seen.

The principal feature in the Vicentini and Pacher seismographic arrangements are, first, the large masses that are used as steady points; and secondly, the ingenious and beautiful manner in which movements relatively to these are mechanically magnified and recorded with a minimum of friction. In all instances the magnification is 100-fold. Light levers to magnify movement relatively to an approximately steady mass have been used by Wagner, Gray, Bouquet de la Grye, Agamennone, Brassart, and very many others. I myself have had perhaps 100 pieces of apparatus thus provided, but in no instance when the multiplication exceeded 20 have I been successful—so long as the method was mechanical—to reach conditions so satisfactory as those attained by Vicentini. Rather than multiplying the relative motion of the pendulum by a single lever, Vicentini employs two short levers, each with a multiplication of 10. These are extremely light, balanced, and connected by an ingeniously constructed link (see references mentioned above). The last lever carries a writing index made from a glass fibre. A piece of glass rod is heated by a blowpipe and flattened with pincers. The flattened portion is again heated and drawn out as a long *flat* fibre about 1 mm. broad. This when broken into lengths each of 4 or 5 ins. is sufficient to form several pointers. One of these is taken and one end of it heated and drawn out to still smaller dimensions. The thin end of this is rounded by bringing it for an instant into contact with the edge of a small flame. To attach such a fibre, say, to the end of the boom of a horizontal pendulum this latter is tipped with a fragment of wax. This is heated with a taper and the thick end of the fibre stuck on to the boom.

We may now imagine the fibre to be floating freely as a prolongation of the boom a centimetre or so above the smoked surface on which it is to write. To bring it into contact with this surface a very small flame is placed for a moment beneath the fibre within 3 or 4 cm. of its end, when the rounded point falls upon the smoked surface and is then in adjustment.

For rapid motion the pendulums behave as steady points, and the movements of the ground are multiplied 100 times, whilst for slow movements the angular deflections of the pendulum are similarly enlarged.

The records are received upon a continuous band of smoked paper moving at a rate of 2 cm. per minute. This band hangs vertically, passing over a roller above and round one below. The axes of these two rollers are not parallel, with the result that the paper travels laterally along the upper drum, and the traces drawn by the pens are parallel spiral lines. Every minute, by electrical connections with a clock, time marks are made upon the band. The Vicentini seismographs are now installed at Rocca di Papa, Verona, Siena, and Laibach.

*Strassburg.*

When I entered the magnificent buildings which constitute the University of Strassburg I felt that I was upon ground which the investigations of the late E. von Rebeur-Paschwitz had made classical. In a few minutes, in company with the genial Professor Gerland and his assistant Dr. R. Ehlert, I was engaged in inspecting seismograms from the Ehlert three-component pendulums. These are recorded on a band of photographic paper, about 21 cm. broad, moving at a rate of 12 cm. per hour. This, with chemicals and other materials, costs about 36*l*. per year. By examining the traces with a magnifying glass, it seems that they consist of a fine series of zigzags, indicating that the pendulums are always in motion. Inasmuch as the removal of the calcium chloride from the pendulum cases does not affect their movements, and because the temperature changes in the chamber where the pendulums are installed is small, it is just possible that these movements may be the result of the city traffic. If this is so, then the movements should be less pronounced at night and more pronounced on public holidays, and at times when traffic is unusually increased. The fact that the tremors produced in a seismograph by a passing carriage or train commence and end suddenly, however, weakens such a supposition.

At present the pendulums are installed on an insulated column in a chamber beneath the Astronomical Observatory (for description of the apparatus see 'Beiträge zur Geophysik,' Band III. Heft 1–3). In the original design of Von Rebeur a complete pendulum weighed 42 gms., and two might be used at right angles to each other.

Each of Dr. Ehlert's pendulums weighs 200 gms., and three are arranged, at angles of 120° with each other, inside a cylindrical iron case. The weights of these pendulums are at their outer ends, near the centre of the casing. By screws from the outside of this case the vertical axes of each of three pendulums can be inclined forwards or laterally. The adjustments, therefore, are not dependent upon screws in a bed plate. The greater weight concentrated at the outer end of each pendulum results in greater certainty of obtaining a steady point for rapid movements of the ground, and hence, perhaps, the continual movement. With three components a direction of motion can be obtained, whilst a very slight movement (the components of which might not be visible on two pendulums) might be recorded on a pendulum to which its direction was nearly at right angles. Each pendulum carries a mirror which reflects a beam of light from a lamp standing near the record-receiving surface 4 metres distant. In front of this there is a cylindrical lens to bring the beams to a focus before impinging on the paper. The clock which drives this band every hour raises a screen which eclipses the beam of light from a fixed mirror in the pendulum case, and in this way gives on the datum line a series of time marks. With a period of 12 seconds one millimetre deflection on the record corresponds to a tilting of $0''\cdot058$.

After visiting the director of the observatory, Professor Becker, who for so many years carried on observations with Von Rebeur's pendulum, Dr. Gerland showed me the site of the Seismological Institute, which next year will be erected within the University grounds. The Government grant for this building is 70,000 marks, or 3,500*l.*, with an annual allowance of 5,500 marks, or 275*l.*, for its maintenance. It is expected that the latter sum will be increased. To commence with, the instruments which it is proposed to instal are Dr. Ehlert's pendulums, a Vicentini pendulum, and a Milne pendulum similar to those established by the B.A. Committee.

As a correction and extension of the second and third paragraphs of the Report of 1897, p. 129, I learned from Dr. G. Gerland that the idea of an international organisation for the observation of earthquakes was first brought forward by the late Dr. E. von Rebeur-Paschwitz and himself in October 1894. At the end of 1894 and the beginning of 1895 they prepared a definite appeal to the scientific world to carry out their suggestions: this appeal, written by Dr. von Rebeur, was subscribed by a series of prominent learned men and was published in the 'Beiträge zur Geophysik,' edited by Professor Gerland, Band II. p. 773.

After the death of Dr. von Rebeur Dr. Gerland naturally felt pledged to continue the work which he had co-operated to inaugurate. Subsequent issues of the propositions therefore appeared under the name of Dr. Gerland, who in 1895 brought the same to the notice of the International Geographical Congress in London.

Briefly stated, they were to establish a centre for the collection and publication of reports relating to *all* earthquakes which are from time to time recorded throughout the world.

It was proposed to issue these reports in Dr. Gerland's geophysical journal.

The most important records would be those obtained from horizontal pendulums, ordinary long pendulums, and bifilar pendulums, and as a commencement it was suggested that ten observing stations should be established round the world.

The positions of these stations were chosen with regard to Japan, from which country large earthquakes frequently radiate.

The Congress passed a resolution respecting the desirability of carrying out Dr. Gerland's proposal.

Very shortly we may expect to see the publication of the first part of the great work which Dr. Gerland has undertaken, in connection with which the reports issued by this committee will undoubtedly prove an assistance.

## Conclusion.

In connection with the instruments which I saw in Italy and at Strassburg, I will first consider those which are employed to record local disturbances or the short-period movements which we can feel.

In Japan I once used a pendulum carrying 80 lb., and 40 feet in length; two pendulums, each of which carried 32 lb., and were 36 feet in length, and very many 3 or 4 feet in length, carrying heavy disc-like bobs. Some of these recorded by light pointers resting on stationary or moving smoked-glass surfaces, whilst others recorded the relative motion of the pendulum with similar pointers attached to the end of light levers, which multiplied the movements of the pendulums.

Professor J. A. Ewing established in Japan a heavy pendulum 20 feet in length, the movements of which relatively to the ground were recorded as two components by means of short levers.

The result of our experience with these instruments, which extended over several years, was that, although they occasionally yielded useful diagrams of local disturbances, it so often happened that an earthquake took place which had a period approximately agreeing with the natural period of the pendulums that these were set in violent motion.

Inasmuch as the period of local earthquakes is for the most part less than three seconds, whilst the period of the long pendulum at Catania is ten seconds, the bob of this instrument becomes a practically steady point for such disturbances.

Directly, however, we turn to the pendulums one or two metres in length which we find so largely employed in the Italian Peninsula, it seems impossible that the character of the seismograms of local shocks which they furnish should not be largely affected by the free period of these instruments.

I—and I think I may add all observers who have had experience with the ordinary pendulum type of apparatus, and also with the long-period duplex pendulums and the steady point bracket seismograph used in Japan, not only in recording actual earthquakes, but also in testing such instruments by subjecting them to artificially produced earthquake-like movements, which movements were absolutely measurable—would not hesitate in adopting the two latter types of apparatus in preference to those in which the principal feature is the bob of an ordinary free pendulum.

Directly we turn to a consideration of the form of apparatus best adapted to record the movements due to earthquakes which have originated at great distances we are upon uncertain ground.

What is chiefly required is to determine the time at which a movement commences, the duration of its various phases, and to measure its varying amplitudes, periods, and directions.

A source of error, especially with regard to the measurement of amplitude or angular motion, rests in the fact that the periods of various phases of earthquake motion may vary between as much as five and sixty seconds. The consequence of this is that at some time or other there is synchronism between the natural period of the instrument and that of its moving platform, with the result that records may be greatly distorted.

A good illustration of the difference in records obtained from different instruments is seen when we compare the records of horizontal pendulums and those of the vasca sismica (see p. 263).

Dr. Cancani's observations on the great Indian earthquake of 1896 (p. 207) also show the amount of difference which may be expected in seismograms obtained from pendulums varying in period.

From what we know at present, seismograms which are trustworthy in their main features are yielded by apparatus which for rapid preliminary tremors records the same relatively to a steady point; and if the pendulum has a natural period of ten to fifteen seconds it apparently follows the slow movement of the succeeding waves.

To extend our knowledge on this subject a central station might be provided with a number of instruments having different periodic motion. Inasmuch as very long pendulums, as at Catania, shorter pendulums or horizontal pendulums with a high multiplication, as at Padua and Strassburg, are affected by wind and other activities disturbing their supports, which at the latter place result in what appears to be continuous movement, it is likely, and in some instances it is certain, that the preliminary tremors of an earthquake have been eclipsed, and its commencement therefore been rendered uncertain.

The general direction in which motion has advanced is known from the time records obtained at several stations. The varying directions at which the ground has moved at a given station may from an instrument recording movements as two rectangular components be sometimes determinable. Usually, however, we are left to choose between two directions.

The records from Dr. Ehlert's pendulum and the apparatus of Vicentini remove such doubts.

As to whether a seismogram can or cannot be analysed with regard to the period and amplitude of separate waves simply depends upon the speed at which the record-receiving surface is moved.

Contrasting the various types of instruments last referred to with the type of instrument adopted by this committee, considering the object in view, there does not appear to be any necessity to regret the choice which they have made.

Each instrument has its merits, and for particular purposes may be better than any other. It was impossible for the committee to have adopted either the long pendulums or large horizontal pendulum of Italy on account of the difficulty of their installation. The Strassburg pendulums, although most desirable at a central station, require a too carefully insulated installation, and entail too much expense for photographic materials to put them within the reach of ordinary observers.

Like the Ehlert pendulums, another instrument equally desirable at a central station is the Vicentini pendulum. However, as this requires the addition of a chronometer and delicate manipulation to insure similarity in adjustment, and a somewhat high and solid supporting wall or pier, it is likely that private observers might find difficulty in its adoption.

For further information respecting the various types of seismographs here mentioned the reader is referred to the British Association Report for 1896, p. 182.

From the preceding notes it is clear that in Italy and Germany seismological investigation receives substantial recognition.

For many years past in the former of these countries observatories have been established, at each of which we find a resident observer, his assistant and custodian with their necessary dwellings, offices, and workrooms. When first established the object of these institutions was to record and study the more or less violent movements of the earthy crust which can be felt. To this was added the observation of the ubiquitous so-called earth tremors, and partly, perhaps, because it was found that these latter in particular were closely associated with certain meteorological conditions, the system was incorporated with the Meteorological Bureau.

During the last few years the observations have been extended to *embrace those of movements due to earthquakes which originated at great* distances. These unfelt movements of the earth's crust, which are as frequent in Great Britain as they are in the Italian Peninsula, are those which at present receive the greatest attention.

It has no doubt been largely due to the discovery that earthquakes can be recorded in any one country as well as in any other that the German Government has been led to devote so large a sum for the establishment of a central observing station in Strassburg, and at the University of Göttingen provision has been made for a professorship of earth physics.

In Austria, for some time past, the Kaiserliche Akademie der Wissenschaften has had its earthquake commission, which has issued publications and established several earthquake stations provided with the Rebeur-Ehlert pendulums.

The Central Observatorium of St. Petersburg has established several stations somewhat similar to those in Austria, and in both countries the means for observing especially the unfelt earthquakes is being extended.

The elaborate system of earthquake observation which has been in existence for many years in Japan is too well known to require description. This is now being extended to embrace observations on earth movements not recordable by ordinary seismographs. In addition to the bureau which reports upon ordinary earthquakes, which forms portion of the meteorological department and a chair of seismology at the University, there is a large committee composed of practical engineers and others whose chief work it is to carry out investigations which may lead to the mitigation of earthquake effects. In connection with the first year's work of this committee the Government grant was 5,000*l.* Inasmuch as practical results have been obtained from this committee every year, I believe a substantial sum of 1,000*l.* or 2,000*l.* appears in the Parliamentary estimates for a continuation of their investigations.

It will no doubt be of interest to this committee to note that means which experience has demonstrated lead to the mitigation of earthquake effects, have during the past year received the consideration of the English Government and private companies in connection with reconstruction after severe earthquakes in the West Indies and Assam.

The inauguration of the investigations which led to the demonstration of these means was in great measure due to the support which this Association has from time to time given to their committees.

## XIII. *Preliminary Examination of Photograms obtained with the Seismometer in the Liverpool Observatory. By* W. E. PLUMMER.

In August 1897 the Seismological Committee of the British Association entrusted one of their seismometers to my care. It was mounted by Mr. Horace Darwin in a cellar of the Observatory, and the photographic record of the motion of a spot reflected from the mirror has been maintained since, save for a few interruptions arising from the failure of the clock or some temporary disturbance. The instrument itself has been described by Dr. Davison in 'Nature,' l. 246, and the general arrangement of the apparatus there detailed, the method of determining the scale, and the directions for the use of the instrument, have been followed without alteration at the Liverpool Observatory. The instrument is arranged to measure tilts or displacements in the plane of the prime vertical : the mirror being in this plane, that of the suspending wires being at right angles. Disturbances are shown by the motion of a spot of light being carried to the east or west of its normal position. The more noticeable deviations from uniformity have been reported to Professor J. Milne as produced probably by earthquake shocks; the dates of these interruptions appear in another part of the report. The instrument, however, does not seem very well adapted for the measurement and discussion of these irregular motions. Some difficulty arises from the smallness of the time scale (10 m.m. of paper passing in an hour), in consequence of which small rapid vibrations are indistinguishable, while the sensitiveness of the instrument as at present used does not seem to be sufficiently great to record the characteristic motion. In Dr. Davison's instrument a displacement of the spot of light through 3·44 inches corresponded to a tilt of the mirror of one second of arc. I endeavoured at first to reach this degree of sensitiveness, and met with difficulties, some of which will be mentioned later. But a recommendation was sent to me last May by Professor Milne to so arrange the instrument that a tilt of the ground of two seconds should move the spot of light on the scale 1·74 inch. I have endeavoured to conform to this direction with the result that the instrument appears more stable, and the trace produced on the sensitised paper seems still more adapted to the discussion of the bending of the earth's crust throughout considerable periods of time than for the observation of the pulsations produced by irregular and violent shocks. The following discussion is therefore confined entirely to the uniform behaviour of the spot of light.

For a very considerable time after the instrument was mounted the photographic trace showed such a continual and rapid motion towards the east that all other effects were completely masked. This was no doubt due to a want of stability in the steel rod carrying the instrument, which had not yet come to a position of rest. The frequent alteration of the foot-screws, always in one direction, necessary to bring the spot of light back on the scale, disturbed the level to such an extent that the sensitiveness varied considerably. This was no doubt assisted by a motion of the rod in the plane of the meridian, which would alter the horizontal distance between the points of suspension of the wire carrying the mirror : a motion which would not be visible on the photographed trace. About November the constant motion of the mirror became less recognisable, and the series of measures here described was begun in January of this year, at which time it is hoped the instrument had settled into its normal conditions. The scale for converting the linear displacement of the photographic trace into seconds of arc still continues, however, to give some trouble, and this feared irregularity in the scale has prevented the use of many of the records in the following discussion. The scale, it may be as well to explain, is determined by turning the mirror through a known angle by means of a rocking-arm, capable of being moved from a distance by the alternate inflation of one or other of two india-rubber balls. It has been the rule to move this rocking-arm once a day, and those records are considered trustworthy when the linear displacement of the light is the same at the beginning and end of the day. When the displacement is not accordant there seems to be no way of making the observations available for discussion. Moreover, it is found practically that very different intervals of time are required to bring the mirror to a state of rest. Sometimes the motion goes on for three or four hours after the initial disturbance, usually much less. I can offer no explanation of these anomalies. I merely mention them here to show that the amount of material at my disposal is not so great as I could wish : that a much longer time is necessary to remove the instrumental and systematic errors, and that the present result is a preliminary inquiry now offered to show what use has been made of the instrument entrusted to my care.

However distrustful one may be of the result, and however cautiously one may feel it necessary to speak of the numerical values obtained, it is impossible to doubt the general character of the motion of the mirror, notwithstanding the small angles with which we have to deal. A mere glance at the record for any one day is sufficient to show the general features of the curve, and herein I believe the motion in the prime vertical agrees with that derived from meridional displacement, though to what extent the motion precedes or follows that on the meridian I have no data to offer. On all days on which the photographic trace has offered no suspicion of unsteadiness in the scale value, or where no interruption of the trace has been made for more than twenty-four hours, the ordinates of the curve have been measured from the time traced for each hour. These ordinates have been read off to the tenth of a millimetre, corresponding usually to about 0·004 of a second of arc, consequently the third place of decimals has been retained, but simply as a matter of calculation. These measures have been grouped in monthly periods, for it was soon apparent that the time of maximum displacement was not constant throughout the year. The mean values of the ordinates for each month have been compared with Bessel's Interpolation Equation for expressing in the usual periodic formulæ the reading at any hour of the day, reckoned from noon, in terms of the mean value and the hour of the day. Supposing the general expression for the value of the measured ordinates at the hour $\frac{n}{15}$ after noon to be represented by the formula

$$D_x = D + a\sin(x+A) + b\sin(2x+B) + c\sin(3x+C),$$

the following table will give the value of the constants D, $a$, $b$, $c$, A, B, C, derived from the solution of the equations formed by the substitution of the mean monthly ordinates for every two hours in the general expression :—

TABLE I.

| Month | D | $a$ | $b$ | $c$ | A | B | C |
|---|---|---|---|---|---|---|---|
| | ″ | ″ | ″ | ″ | ° ′ | ° ′ | ° ′ |
| January . . | 0·000 | 0·0194 | 0·0421 | 0·0145 | 8 5 | 270 29 | 65 30 |
| February . . | − ·005 | ·0281 | ·0457 | ·0143 | 4 54 | 257 53 | 358 2 |
| March . . | + ·001 | ·0292 | ·0529 | ·0092 | 32 11 | 285 30 | 142 11 |
| April . . | − ·004 | ·0264 | ·0496 | ·0079 | 30 50 | 322 16 | 196 30 |
| May . . . | − ·011 | ·0185 | ·0572 | ·0046 | 45 0 | 309 30 | 278 51 |
| June . . | − ·008 | ·0363 | ·0583 | ·0170 | 92 32 | 287 9 | 29 27 |
| July . . . | − ·003 | ·0527 | ·0483 | ·0074 | 112 17 | 343 17 | 72 33 |
| August . . | − ·003 | ·0136 | ·0670 | ·0069 | 118 36 | 283 33 | 288 11 |

The principal maximum values, both positive and negative, for each month as derived from the forementioned equation are as follows :—

## Table II.

| Month | Time of Maximum Displacement | Amplitude | Month | Time of Maximum Displacement | Amplitude |
|---|---|---|---|---|---|
| | H. M. | ″ | | H. M. | ″ |
| January . | 6 17 P.M. | +0·0603 | May . . | 4 27 P.M. | +0·0781 |
| ,, . | 0 34 A.M. | − ·0602 | ,, . . | 10 55 ,, | − ·0635 |
| ,, . | 5 24 ,, | + ·0323 | ,, . . | 5 1 A.M. | + ·0377 |
| ,, . | 10 21 ,, | − ·0353 | ,, . . | 10 34 ,, | − ·0524 |
| February . | 6 34 P.M. | + ·0597 | June . . | 4 10 P.M. | + ·0516 |
| ,, . | 1 26 A.M. | − ·0645 | ,, . . | 0 3 A.M. | − ·1006 |
| ,, . | 6 15 ,, | + ·0319 | ,, . . | 5 48 ,, | + ·0735 |
| ,, . | 11 4 ,, | − ·0497 | ,, . . | 10 30 ,, | − ·0279 |
| March . . | 5 48 P.M. | + ·0841 | July . . | 3 20 P.M. | + ·0690 |
| ,, . . | 11 32 ,, | − ·0732 | ,, . . | 9 36 ,, | − ·1038 |
| ,, . . | 5 27 A.M. | + ·0221 | ,, . . | 4 38 A.M. | + ·0351 |
| ,, . . | 11 5 ,, | − ·0337 | ,, . . | 10 8 ,, | − ·0048 |
| April . . | 4 31 P.M. | + ·0803 | August . . | 4 57 P.M. | + ·0642 |
| ,, . . | 10 30 ,, | − ·0592 | ,, . . | 11 24 ,, | − ·0727 |
| ,, . . | 3 43 A.M. | + ·0210 | ,, . . | 5 57 A.M. | + ·0738 |
| ,, . . | 9 36 ,, | − ·0412 | ,, . . | 11 32 ,, | − ·0612 |

## Table III.

| | January | February | March | April | May | June | July | August |
|---|---|---|---|---|---|---|---|---|
| Noon | −0″·005 | +0″·009 | −0″·001 | +0″·011 | +0″·001 | +0″·019 | −0″·017 | −0″·014 |
| 1 P.M. | − ·003 | − ·006 | + ·017 | − ·002 | + ·011 | + ·004 | + ·019 | − ·012 |
| 2 ,, | − ·007 | − ·008 | − ·013 | − ·004 | − ·011 | − ·008 | + ·004 | + ·003 |
| 3 ,, | + ·017 | − ·012 | − ·006 | + ·017 | − ·008 | − ·010 | − ·021 | + ·011 |
| 4 ,, | − ·003 | + ·013 | ·000 | − ·005 | + ·010 | + ·005 | − ·014 | + ·018 |
| 5 ,, | + ·006 | + ·005 | + ·022 | − ·003 | − ·019 | + ·013 | − ·005 | + ·016 |
| 6 ,, | + ·003 | + ·014 | + ·013 | − ·010 | − ·001 | − ·005 | + ·006 | − ·007 |
| 7 ,, | − ·019 | − ·001 | − ·011 | ·000 | + ·013 | − ·015 | − ·001 | − ·014 |
| 8 ,, | + ·010 | − ·014 | − ·017 | + ·006 | + ·005 | + ·009 | + ·001 | − ·017 |
| 9 ,, | + ·006 | + ·001 | − ·020 | + ·022 | + ·003 | + ·001 | − ·001 | − ·019 |
| 10 ,, | + ·005 | + ·013 | + ·003 | + ·012 | − ·024 | + ·004 | + ·001 | + ·008 |
| 11 ,, | ·000 | − ·002 | + ·007 | + ·003 | − ·009 | − ·010 | ·000 | + ·006 |
| Midnt. | − ·009 | − ·015 | − ·004 | − ·017 | − ·011 | − ·005 | − ·001 | + ·019 |
| 1 A.M. | + ·021 | + ·003 | + ·002 | − ·006 | + ·008 | + ·019 | ·000 | − ·002 |
| 2 ,, | − 002 | − ·002 | − ·011 | + ·002 | − ·008 | − ·006 | − ·009 | + ·007 |
| 3 ,, | + ·003 | − ·001 | − ·019 | − ·019 | − ·006 | − ·008 | + ·015 | + ·005 |
| 4 ,, | + ·005 | + ·013 | + ·016 | − ·014 | + ·006 | + ·008 | − ·003 | − ·022 |
| 5 ,, | − ·013 | − ·008 | + ·010 | + ·001 | − ·006 | − ·019 | ·000 | + ·005 |
| 6 ,, | + ·003 | + ·021 | − ·003 | − ·007 | + ·014 | − ·013 | − ·001 | + ·021 |
| 7 ,, | − ·019 | + ·002 | − ·001 | + ·003 | + ·025 | + ·017 | + ·009 | − ·011 |
| 8 ,, | − ·007 | − ·002 | + ·004 | − ·014 | − ·001 | − ·014 | + ·006 | − ·010 |
| 9 ,, | + ·006 | + ·002 | + ·014 | − ·016 | + ·012 | + ·001 | + ·016 | + ·013 |
| 10 ,, | − ·008 | + ·007 | − ·016 | + ·022 | + ·007 | − ·001 | − ·007 | − ·003 |
| 11 ,, | − ·010 | − ·006 | − ·008 | + ·009 | − ·002 | − ·005 | − ·019 | + ·007 |

The meaning of the positive sign in Table II. and elsewhere is that the spot of light has travelled towards the east. So far as Table II. shows anything, it exhibits a tendency for the first eastern elongation, that in the afternoon, to occur earlier in the day as the year advances, also that the amplitude of the afternoon excursion, whether east or west, is greater than that in the morning, and that the maximum effect occurs in

T 2

the summer months. It would be wrong to insist too strongly even on these tendencies considering that only a part of one year has been examined, and certainly premature to suggest any physical interpretation. I hope, however, that this partial result may prove of sufficient interest to induce the Committee to sanction further inquiries of the same nature, for which I think the instrument is peculiarly well fitted. Lastly, I give in a tabular form (Table III.) the difference (C−O) between the mean monthly result at each hour of the day, derived from the photograms, and the values computed from the interpolation equation.

### XIV. *Reports on Seismological Investigations published by the British Association.*

| | | PAGE |
|---|---|---|
| 1841. | Report on Instruments to record Earthquakes in Scotland and Ireland. Drawn up by Lord GREENOCK and DAVID MILNE | 46–50 |
| 1842. | Report on Registering Shocks of Earthquakes in Great Britain. By DAVID MILNE | 92–98 |
| 1843. | Report on Registering Shocks of Earthquakes. WM. BUCKLAND, DAVID MILNE | 120–127 |
| 1844. | Report on Earthquake Shocks in Scotland. DAVID MILNE | 85–90 |
| 1847. | Report on Geological Theories of Elevation and Earthquakes. WILLIAM HOPKINS, M.A., F.R.S. | 33–92 |
| 1850. | First Report on the Facts of Earthquake Phenomena. ROBERT MALLET, C.E., F.R.S. | 1–89 |
| 1851. | Second Report on the Facts of Earthquake Phenomena. ROBERT MALLET, C.E., F.R.S. | 272–320 |
| 1852. | Third Report on the Facts of Earthquake Phenomena. ROBERT MALLET, C.E., F.R.S. | 1–176 |
| 1854. | Third Report (continued) on the Facts of Earthquake Phenomena. ROBERT MALLET, C.E., F.R.S. | 1–326 |
| 1854. | Report on Earthquakes and Seismometers. Col. PORTLOCK, R.E., F.R.S. | 370–372 |
| 1858. | Fourth Report on the Facts of Earthquake Phenomena. ROBERT MALLET, C.E., F.R.S. | 1–136 |
| 1861. | Experiments at Holyhead on the Transit Velocity of Waves analogous to Earthquake Waves. ROBERT MALLET, C.E., F.R.S. | 201–236 |

Reports on the Earthquake Phenomena of Japan, drawn up by John Milne, were issued, under varying titles, yearly from 1881 until 1895.

In 1895 the 'Earth Tremor' Committee, appointed to investigate earth tremors in Great Britain, issued the last of a series of Reports dated 1893, 1894, and 1895, the Secretary being Mr. C. Davison.

In 1896 Committees on the Earthquake Phenomena of Japan and Earth Tremors were united under the joint secretaryship of C. Davison and J. Milne for the purpose of carrying on seismological investigation, and have issued their First, Second, and Third Reports.

The British Association has issued since 1841 about thirty-seven Reports relating to earthquakes.