REPORT

OF THE

EIGHTY SEVENTH MEETING OF THE

BRITISH ASSOCIATION

FOR THE ADVANCEMENT OF SCIENCE

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Seismological Investigations.—Twenty-third Report of the Committee, consisting of Professor H. H. TURNER (*Chairman*), Mr. J. J. SHAW (*Secretary*), Mr. C. VERNON BOYS, Dr. J. E. CROMBIE, Sir HORACE DARWIN, Dr. C. DAVISON, Sir F. W. DYSON, Sir R. T. GLAZEBROOK, Professors C. G. KNOTT *and* H. LAMB, Sir J. LARMOR, Professors A. E. H. LOVE, H. M. MACDONALD, J. PERRY, *and* H. C. PLUMMER, Mr. W. E. PLUMMER, Professors R. A. SAMPSON *and* A. SCHUSTER, Sir NAPIER SHAW, Dr. G. T. WALKER, *and* Dr. G. W. WALKER.

General.

THE Committee asks to be reappointed, with a grant of 100*l.* (including printing), in addition to 100*l.* from the Caird Fund already voted. The Government Grant Fund administered by the Royal Society has voted a subsidy of 200*l.* for 1919, as in recent years.

It was hoped that some modification of this application might have been made this year. Under the auspices of the International Research Council, which met at Brussels July 18-28, a Geodetic and Geophysical Union was constituted, with Seismology as one of its sections. This involves ultimately the establishment of a Seismological Bureau or Central Office, where different records may be collated and discussed, and experimental and standardisation work carried out; and in view of all the circumstances (including the death of Prince Galitzin and the uncertain future of seismology in Russia, the interruption of relations with Germany, and the previous history of seismology in the British Empire) it was hoped that some locality in England, and probably Oxford, might be chosen as the locality for the Bureau.

In anticipation of the Brussels meeting a National Research Council for Geophysics had been constituted under the auspices of the Royal Society, and at the meeting of this Council on June 20 the following resolution was adopted, on the motion of Professor Schuster:—

> 'That an offer be made to the Section of Seismology of the International Union of Geodesy and Geophysics to locate its Central Bureau at Oxford; but that the Executive Committee of the Section have power to transfer it to another locality in Great Britain on the recommendation of the National Research Council for Geophysics in that country.'

When, however, the location of the Central Bureau came up for preliminary discussion at Brussels, it was found that the French were anxious that the claims of Strasbourg, now so dramatically restored to them, should be considered. As a possible way of meeting both wishes, a division of the work of the Bureau between Strasbourg and Oxford was suggested; but at this point it was remarked that there were still some points to be settled in connection with the formerly existing International Seismological Association, and ultimately it was decided to defer the formation of the Seismological Section until these points had been finally disposed of, for there was a general agreement that a totally new departure, untrammelled by links with the past, was desirable at this juncture. Hence no definite steps towards the formation of a Seismological Section were taken at Brussels, and the work of the Committee will proceed as nearly as possible on the same lines as before for the next year or two.

But an important change of locality has become inevitable. On the approach of Peace, Mrs. Milne decided to return to Japan as soon as her voyage could be arranged. This involved the sale of the house at Shide to which the Milne Observatory (partly a disused stable, partly an office specially built) is attached, and it was not feasible to continue the use of the observatory under these conditions. As a provisional measure the instruments and apparatus are being transferred to Oxford, where a Milne-Shaw machine had already been set up (see last Report), and where the facilities temporarily accorded by Mr. James Walker have been kindly continued by the newly appointed Professor (Dr. F. A. Lindemann). At the moment of writing this transference is not complete, and a fuller account of it is deferred to the next report.

Instrumental.

Wireless time signals were received at Shide regularly up to the time of removal of the seismographs. The transit lent by the Royal Astronomical Society has been returned.

The wireless receiving apparatus which had been installed at Oxford before the War, but taken down on the commencement of hostilities, was again set up last autumn, and signals have been regularly received.

Milne-Shaw Seismographs.

One of these was set up in the Clarendon basement at Oxford by Mr. J. J. Shaw on October 8, 1918, just in time to catch the big earthquake of October 10. Others are completed, or nearly completed, but it will be convenient to defer details of their installation to the next report. One of them has been installed by Mr. J. J. Shaw for trial in a 'dug-out' at some distance from his house at West Bromwich, and some interesting results obtained. But of these again details are deferred. The past year, owing to the cessation of hostilities, has brought with it so many needs and distractions that this report is necessarily somewhat imperfect.

Suggested Corrections to Adopted Tables.

This work is proceeding. The suggested corrections are being applied provisionally to obtain new determinations of epicentres in the cases of well-observed earthquakes. This second approximation should show how far the corrections are valid. The work is, however, somewhat extensive, and no report can be profitably made as yet.

Earthquake Periodicity.

In the 1912 Report of this Committee evidence was given for the existence of a periodicity of nearly 15 months (there identified as

104/7 months) deducted from the *Catalogue of Destructive Earthquakes* compiled under Milne's superintendence. It was natural to examine the independent *Catalogue of Chinese Earthquakes* compiled by Milne's Japanese assistant, Shinobu Hirota, and published in the 1908 Report of this Committee (Section XI.), with additions by Professor E. H. Parker in the 1909 Report (Section XII.). The result was to confirm the periodicity and to define it more exactly as of period 451·805 days= 14·8438 months=1·2370 years. The investigation is given in the Monthly Notices R.A.S., lxxix., p. 461, and it is pointed out that the periodicity seems to be affected by one of long period (about 78 years). This led to the examination of the same Chinese series for long periods (see *Mon. Not. R.A.S.* lxxix., p. 531), of which several seem to be worth further investigation. The most notable is not the one above mentioned (78 years), but one of about 240 years (which may therefore be 3×78 years), which is conspicuous in the Chinese earthquakes and was also found in the records of Nile flood. It is, however, only faintly traceable in Milne's *Catalogue of Destructive Earthquakes*, and the question arises how far the heterogeneous nature of the latter can be held responsible for the loss of this periodicity, and how far, on the other hand, the Chinese records can be regarded as possessing the necessary homogeneity. There is no doubt of the defective nature of the material in the *Destructive Earthquakes* in the early centuries. The increase in volume of the records is so considerable as quite possibly to overwhelm any signs of periodicity. For example, let us limit attention to European earthquakes and to those marked III. by Milne (*i.e.*, as 'having destroyed towns and devastated districts'). It might be supposed that these would be recorded with some approach to completeness, yet the numbers for successive periods of 180 years are as shown:—

AD 631 — 811	— 991	— 1171	— 1351	— 1531	— 1711	— 1891
11	9	14	22	19	39	117

Unless there has been an improbable increase in the number of such quakes, the figures for 1711–1891 show that only about one in ten was recorded in earlier centuries. If this happens for European records, others will scarcely be in better case, and when we compound the different sources it is perhaps not surprising if the accidental errors are large enough to mask periodic phenomena.

The Chinese records are also probably far from complete, but they have an appearance of much greater steadiness of some kind, which may quite possibly be real. A critical discussion by Chinese scholars would be of great interest.

Meanwhile we turn to some numerical relations among the periodicities indicated, which seem to strengthen the evidence for their reality.

Firstly, remark that the period of 451·805 days (or 1·2370 years) is sensibly different from that found for the movements of the earth's axis from astronomical observations. The most recent discussion of this latter period by Sir F. W. Dyson (*Mon. Not. R.A.S.*, lxxviii., p. 452) gives it as about 432 days, or accurately 7·10/6 years= 1·1833 years. Neither determination can be so much in error as

20 days. We must apparently recognise two distinct periodicities connected in some way with our earth, and our attention is naturally directed to possibilities of interference.

$$\text{Now} \quad 21 \times 1{\cdot}23698 \text{ years} = 25{\cdot}97658 \text{ years.}$$
$$22 \times 1{\cdot}18333 \text{ years} = 26{\cdot}03333 \text{ years.}$$

So that the two periodicities interfere in approximately 26 years. But the differences from 26 years are by no means negligible. If we adopted exactly 26/21 years for the former we should be returning to the period of 104/7 months tentatively deduced from the *Catalogue of Destructive Earthquakes* and shown by the *Chinese Earthquakes* to be in error by about one month in 78 years. The length of the Chinese series warrants our retaining 5 significant figures.

The astronomical determination, though deduced from observations of a much higher order of accuracy, depends on a much shorter series, and the number of significant figures is fewer. Dyson contents himself with 3, and if we vary his last figure by a few units we get:—

$$22 \times 7{\cdot}08/6 = 22 \times 1{\cdot}18000 = 25{\cdot}9600$$
$$22 \times 7{\cdot}09/6 = 22 \times 1{\cdot}18167 = 25{\cdot}9967$$
$$22 \times 7{\cdot}10/6 = 22 \times 1{\cdot}18333 = 26{\cdot}0333$$
$$22 \times 7{\cdot}11/6 = 22 \times 1{\cdot}18500 = 26{\cdot}0700$$

In the first case interference with the earthquake period would take place in rather less than 26 years, in the other cases in rather more. To put the point in another way, let us calculate the period of the earth's axis which would interfere with that deduced from earthquakes (supposed accurate) in various assigned times, say 25 years, 26 years, and 27 years.

Period of Interference	Period of Earth's Axis	Six times
	years	years
25 years	1·1784	7·070
26 years	1·1805	7·083
27 years	1·1825	7·095

It will be seen that if this period of interference could in any way be independently identified we might deduce a close value for the period of the earth's axis.

Now, although this actual period has not as yet presented itself in other connections, its multiples, and perhaps its submultiples, have so presented themselves several times over.

Thus we have:—

$$3 \times 26 \text{ years} = 78 \text{ years}$$
$$6 \times 26 \text{ years} = 156 \text{ years}$$
$$9 \times 26 \text{ years} = 234 \text{ years}$$

The last may possibly be the 240-year period already mentioned as conspicuous in the Chinese earthquakes (*Mon. Not.* lxxix., p. 531) in the Nile floods, and possibly in the motion of the moon. A period of 156 years approximately was found by Mr. A. E. Douglass in the growth of trees (*Bull. Amer. Geog. Soc.* xlvi., pp. 321-335, 1914), and is illustrated by a striking diagram in Professor D'Arcy Thompson's book on *Growth and Form*, p. 122 (Camb. Univ. Press, 1917). The actual length is apparently shorter than 156 years—nearer 150 years, but the material is scarcely sufficient to warrant a very precise estimate. The Chinese earthquakes show this periodicity of 156 years very clearly. Dividing the period into 18 equal parts the totals are as in the columns O, the columns C being calculated from the formula:—

$$C = 45 + 15{\cdot}6 \text{ Cos } (O - 225^{\circ}).$$

Period of 156 *years in Chinese Earthquakes, exhibited in* 18 *groups of* 7 *years.*

O	C	O−C	O	C	O−C	O	C	O−C
29	34	− 5	30	41	−11	59	61	− 2
38	31	+ 7	32	46	−14	54	68	−14
32	30	+ 2	40	51	−11	63	54	+ 9
56	29	+27	69	56	+13	41	49	− 8
30	32	− 2	70	59	+11	32	44	−12
29	36	− 7	66	60	+ 6	35	39	− 4

The differences O—C show a variation in the half-cycle of 78 years, to which attention has already been drawn in the paper on the 15-month period (*loc. cit.*), and, moreover, the phases of the 15-month term vary in this half-cycle of 78 years and in the quarter-cycle of 39 years. This quarter-cycle appears in numerous meteorological phenomena, and should probably replace the supposed 'Brückner Cycle' of 35 years (see *Q.J.R. Met. Soc.* xli., p. 322).

But 39 years is no longer a multiple of 26 years, though related to it. The submultiple of both—*viz.*, 13 years—has, however, been shown to affect a large number of meteorological phenomena, being a double 'chapter' of the kind indicated in the paper just cited, and others which have followed it.

As yet it cannot be said that we have anything really tangible in the shape of a physical hypothesis, but these numerical relations are certainly suggestive, and are sufficient to guide further inquiry. Naturally in tentative exploration of this kind much time is spent in unproductive essays, but this need not be grudged.