THE FREQUENCY OF EARTHQUAKES.[1]

THE publication of an abstract of twenty years' record of earthquakes in Italy gives an opportunity for studying the effect of the gravitational attraction of the sun; the period is so nearly coincident with the lunar cycle of nineteen years that the effect of the moon may be regarded as eliminated, the record is of exceptional continuity and completeness, and the number of observations is large enough to allow of the extraction of groups sufficiently numerous to give good averages.

The distribution of the stresses throughout each diurnal period presents two peculiarities: first, the range of stress is greater during the day than during the night in summer, with an opposite variation during winter; secondly, the general effect of the vertical component is towards a progressive diminution of the downward pressure during the six hours preceding, and towards an increase during the six hours following, the meridian passages at noon and midnight.

Investigating the first of these, a division of the year into two parts, at the equinoxes, gives a proportion of shocks during the day to those during the night, somewhat greater than the average during the summer half, and somewhat less during the winter. As this result might be purely fortuitous it was tested by a similar treatment of two other records which stood ready for use—Milne's catalogue of Japanese earthquakes from 1885 to 1892, and the after-shocks of the Indian earthquake of 1897. They show a variation identical in character with that of the Italian record. A second test depends on the argument that, if the variation is in any way seasonal, the divergence should be increased at the height of each season; the figures for the months of January–February and of June–July were taken out, as representing midwinter and midsummer respectively, and found to show a divergence in each case greater than, and in the same direction as, the respective half-years.

The actual figures are as follows, the frequency being expressed as a ratio to the mean, of each group, taken as 100:—

DISTRIBUTION OF SHOCKS BY DAY AND NIGHT.

Italy, 1891–1910.

	Day	Night
June–July	90	110
Summer half	88	112
Whole year	84	116
Winter half	81	119
December–January ...	77	123

Japan, 1885–1892.

	Day	Night
Summer half	102	98
Whole year	97	103
Winter half	93	107

Assam After-shocks.

	Day	Night
Summer	113	87
Whole record	107	93
Winter	101	99

Taken by itself the variation, as between any pair of ratios, is as likely to be in one direction as in the other, but the odds against a complete concordance throughout the whole series are 31 to 1; it may, therefore, be taken that the variations are not fortuitous, but due to some common cause which tends to increase the frequency during the day and decrease it during the night in summer, with the opposite in winter.

[1] From a paper entitled "Some Considerations arising from the Frequency of Earthquakes," read before the Geological Society on February 6 by R. D. Oldham, F.R.S.

For the second line of investigation a computation was made of the mean amount of stress for the whole of Italy and the whole year for each of the six hours preceding and following the meridian passage. These were plotted and compared with the corresponding curve of frequency of earthquakes; the result showed no apparent relation between the frequency and the total, or the horizontal, stress, though a close one with the variation of the vertical stress, the greatest number of earthquakes being in the period in which there is the greatest increase of downward pressure. As the rate of increase diminishes the frequency of shocks is less, suffering a further diminution as the pressure begins to decrease, and reaching its minimum in the period where the decrease in pressure is greatest, increasing again in the same way to the maximum.

The Japanese record is not directly comparable with the Italian, being dominated by the after-shocks of great earthquakes of the world-shaking type, and nearly half of the whole record consists of after-shocks of the Mino-Owari earthquake of 1891. Taking these separately, we get a curve of frequency similar to the Italian, except that the maximum and minimum are reversed, the greatest number of shocks corresponding with the period when the load is being lightened most rapidly, indicating that these shocks were due to a general movement of elevation rather than depression, a conclusion in accord with field observations of other great earthquakes.

The actual figures of variation of stress, in Italy, and the frequency of earthquakes are as follows:—

Hours ... ... XII II IIII VI VIII X XII

Mean range of vertical stress in each two hours, Italy.	−0·14	−0·27	−0·13	+0·13	+0·27	+0·14
Ratio of actual to mean frequency of each two-hour period, Italy, 1891–1910... ...	1·06	1·17	1·01	0·90	0·88	0·99
After-shocks of Mino-Owari, Oct. 28, 1891, Japan.	1·01	0·95	0·96	0·97	1·08	1·03

The principal point of interest in these figures is that they give a means of estimating the rate of growth of the strain which produces earthquakes. Accepting the hypothesis that earthquakes are due to the relief by fracture of a growing strain when this has reached the breaking point, it can be shown that a variable strain, acting alternately in increase or decrease of the general growth, while leaving the average rate of growth unaltered, will give rise to a corresponding variation in the frequency of shocks in each period, and, besides that, there is a simple relation between the magnitudes of the two stresses, to which the strains are due, and the variations from the mean frequency of earthquakes. A calculation based on this shows that the growth of strain for Italy is such that the breaking strain would be reached in about three and a half years, starting from a condition of no strain. The after-shocks of the Mino-Owari earthquake give about five to six months, if account is taken of the difference between the resistance of rock to tension and compression. These figures are given for what they are worth; at the least they are of interest as being the first authentic estimate which it has been possible to make of the time required to prepare for an earthquake, and, thence, of the rate of growth of the particular tectonic process involved in their production.