REVIEWS

SEISMICITY OF THE EARTH AND ASSOCIATED PHENOMENA. By B. Gutenberg and C. F. Richter, Seismological Laboratory, California Institute of Technology, Princeton University Press, Princeton, New Jersey (1949). Price \$ 10·00.

The book gives an account of the relative seismicity of various parts of the earth based on such available data since 1904, which are regarded as sufficiently reliable. A valuable discussion has been given of the geography and geological character of the zones and areas of seismic activity, including correlation with alignments of active volcanoes and gravity anomalies, and with occeanic deeps, mountain structures, and other topographic features. An examination has also been made of the mechanism, particularly with reference to crustal folding and block faulting.

The book provides extensive tables, giving the locations of earthquakes in geographical order and grouped according to depth, together with carefully assembled chronological lists of the larger earthquakes during the period studied.

In evaluating data, the magnitude scale developed at Pasadena has been used. The magnitude of an earthquake was originally defined for shallow shocks in southern California, as the logarithm of the maximum trace amplitude expressed in thousandths of a millimetre with which the standard short-period torsion seismometer (period 0·8 sec., magnification 2800, damping nearly critical) would register that earthquake at an epicentral distance of 100 kilometers. Magnitudes for well-defined shocks are assigned to the tenth of a unit, with an error ordinarily not exceeding two tenths. The classification by magnitude is defined as,

Class	*a*	*b*	*c*	*d*	*e*
Magnitude	7·8—8.5	7·0—7·7	6·0—6·9	5·3—5·9	below 5·3

In general, it is found that shocks of classes *a* and *b* are recorded at all stations ; class *c* is well-recorded up to a distance of 90° of arc (10,000 km. over the surface of the earth), class *d* up to about 45°, class *e* not beyond 10°. As a result of applying data for P, S, etc., and allowing for the effect of depth (especially for shocks 40—60 km. deep), previously estimated magnitudes of many shocks have been increased. This has occasionally raised a shock from class *c* to class *b* or from class *b* to class *a*.

The relation between magnitude and energy was found to yield the equation.

$$\log E = 11{\cdot}3 + 1{\cdot}8\ M,$$

where M is the magnitude and E is the energy of the shock in ergs. The authors state that this equation may require modification for both theoretical and empirical reasons. The constant term is specially difficult to fix, but this does not affect the determination of magnitudes for deep shocks, nor the relative proportion of energy released in different shocks or in different years. It merely multiplies all calculated energies by a constant.

The section on frequency and energy of earthquakes includes for the first time statistical results for deep focus shocks on the same basis as for shallow shocks. For investigating the distribution of earthquakes in depth, use has been made of the complete list of identified shocks. This has the advantage of dealing with as large numbers as possible, although the process of identification may be slightly selective with respect to depth. It is found that the numbers decrease to a minimum at about 450 km.; there is a clear increase to a minor maximum at about 600 km., beyond which the numbers fall off very rapidly to the deepest shocks known just below 700 km. These general results are confirmed by the use of the smaller aggregate numbers in the range of times and magnitudes considered statistically valid :

Depth (Km)	Shallow	100	150	200	250	300	350	400	450	500	550	600	650	700
Number	800±	139	56	38	15	8	11	12	4	7	8	12	7	3

The Energy, E, is calculated as the mean kinetic energy of a progressive spherical elastic wave. An equal term representing its mean potential energy should be added to this; account has also to be taken of the effect of the free surface. Moreover, there appears to be approximately equal partition of energy between longitudinal and transverse waves, so that the energy calculated for either alone should be doubled. There is also the further question of what fraction of energy liberated in the earthquake is radiated in the form of elastic waves. But assuming the radiated energy to be given by the empirical equation,

$$\log E = 12 + 1{\cdot}8\, M,$$

the authors have given the following values for the energy released in units of 10^{26} ergs for earthquakes of different magnitudes.

Magnitude	7·0	7·1	7·2	7·3	7·4	7·5
E(10^{26} ergs)	·04	·06	·10	·13	·20	·32

Magnitude	7·6	7·7	7·8	7·9	8·0	8·1	8·2	8·3	8·4	8·5	8·6
E(10^{26} ergs)	·50	·79	1·0	1·6	2·5	4·0	6·3	7·9	13	20	25

The energy released by an atomic bomb is stated as equivalent to that in the detonation of 20,000 tons of TNT, and, therefore, of the order of 10^{21} ergs, corresponding to an earthquake of magnitude 5. Other artificial explosions are of much smaller order of magnitude; major quarry blasts rarely reach magnitude $2\frac{1}{2}$.

The authors have also given the values of energy released for each of the years 1904—1945 separately for shallow, intermediate and deep focus earthquakes. The rate of annual energy release is extremely irregular. The calculated energy release of 12×10^{26} ergs annually, on the average, is comparable with the annual flow of heat from the interior to the surface of the earth, which is of the order of 10^{26} ergs, corresponding to 10^{6} calories per second per square centimeter.

Wherever detailed investigation is possible, the majority of normal shallow earthquakes are found to originate at or near the base of the granite layer. This active level varies in depth from region to region. The surface structure of the earth exhibits a number of distinct types, different in their geological history, and each associated with a characteristic pattern of seismicity. The most active of these are the Pacific structural arcs. These are folds developed about the margin of Pacific basin, and elsewhere where regions of different crustal structure are in contact. Where most clearly defined these arcs are still active with earthquakes at all depths, and folding is still in progress. The similar arcs of the Alpine group are less active, and show fewer of the characteristic features. In limited sectors about the Pacific, as well as in other regions, there are conditions such that shearing and strike-slip faulting predominate.

Long fault zones develop ; displacement frequently ruptures the surface. Deep shocks are few or absent. The geological history of the earth has led to the formation of a limited number of stable masses, which have undergone little deformation in the later geological periods. The largest of these is the basin of the central and northern Pacific ocean ; the others are the continental shields or nuclei the Canadian shield, the Brazilian Shield, the Baltic Shield, the Angara Shield in south Central Asia, the African stable mass, the stable region of Central and Western Australia, and the stable masses of Arabia and southern India, with other smaller units.

The authors have given an excellent review of regional peculiarities based on the geographical distribution of seismicity. The active areas of the globe have been divided into numbered regions ; the numbering first makes the circuit-about the Pacific, then covers the trans-Asiatic zone, and follows the remaining active belts and regions of minor seismicity. A discussion has been given of Tsunamics (Seismic Seas Waves) ; the majority of Tsunamics originate and are effective in Pacific area.

A discussion also has been given of the mechanism, which the authors recognise as hypothetical. Seismicity must have changed greatly in the course of geologic time. Contemporary earthquakes only indicate contemporary stresses, displacements and fracturing. The mechanism of stresses in the active zones is of two chief types expressed in folds and in block structures respectively. The former may be seen in the arcuate structures of Pacific type which are well defined regions of folding and trust faulting. A different mechanism not necessarily connected with the stress system producing the active arcs must be postulated for the regions of block and shear faulting, including long sectors of the circum-Pacific belt. The California Region is typical of this group. Deep-focus earthquakes cannot be of the nature of detonations due to rapid local changes of state. The distribution of initial compressional or dilatational motion as recorded at distant stations and the existence of large elastic shear waves radiated directly from the source, leave no doubt that deep shocks are mechanically similar in origin to tectonic shallow shocks.

The collection of materials and discussion in this monograph will be found to be of great value by all seismologists.

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