On Frequency Magnitude and Energy of Significant Indian Earthquakes

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Summary – Frequency, magnitude and energy of Indian earthquakes with magnitude greater than 5 has been studied. The Indian regions can be divided into three main seismically active regions, viz. 1. Delhi and Himalayan region, 2. Assam region and 3. Koyana region which includes south-west India. The relations between frequency-magnitude and energy-magnitude of earthquakes are shown in Fig. 3 and 4 respectively. Further a relationship, $\log N = p + q \log E$ type has been established for frequency and energy of Indian earthquakes and the values of constants p and q have been determined for all the three seismic regions. The results thus obtained are good and satisfactory.

1. Introduction

The seismicity of Indian earthquakes has been an important problem for the seismologist and for the earthquake engineer alike. The study of the various seismically active zones of the Indian regions has been undertaken by various research workers in this field. India can be divided into three major seismic zones (Fig. 1), i.e. 1. Delhi and Himalayan region, 2. Assam region and 3. Koyana region. However, Kashmir and Hindukush regions are likely to fall either in Delhi-Sonepat region or in Himalayan region. The geology and tectonics of the area are main characteristics as far as these seismic zones are concerned. It can further be emphasized that seismic zones are divided on the basis of frequency of occurrence of earthquakes and on the basis of seismic coefficients which are adopted zone-wise.

Seismologists like GUTENBERG and RICHTER [1][3]), BÅTH M. [2] and GUTENBERG [3] have tried to correlate the frequency, magnitude and energy of earthquakes in the past. They have also given several formulae for these parameters. Recently FURUMOTO [4] and BURRIDGE and KNOPOFF [5] have also approached on this problem.

The representation of frequency-magnitude and energy-magnitude of significant Indian earthquakes has been shown in Fig. 3 and 4 respectively. Finally, the following earthquake occurrence law has been derived, $\log N = p + q \log E$, where p and q are constants. Mostly q remains same for all regions but the variation in p has been noted considerably as it depends on the level of seismicity of a region.

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[3]) Numbers in brackets refer to References, page 32.

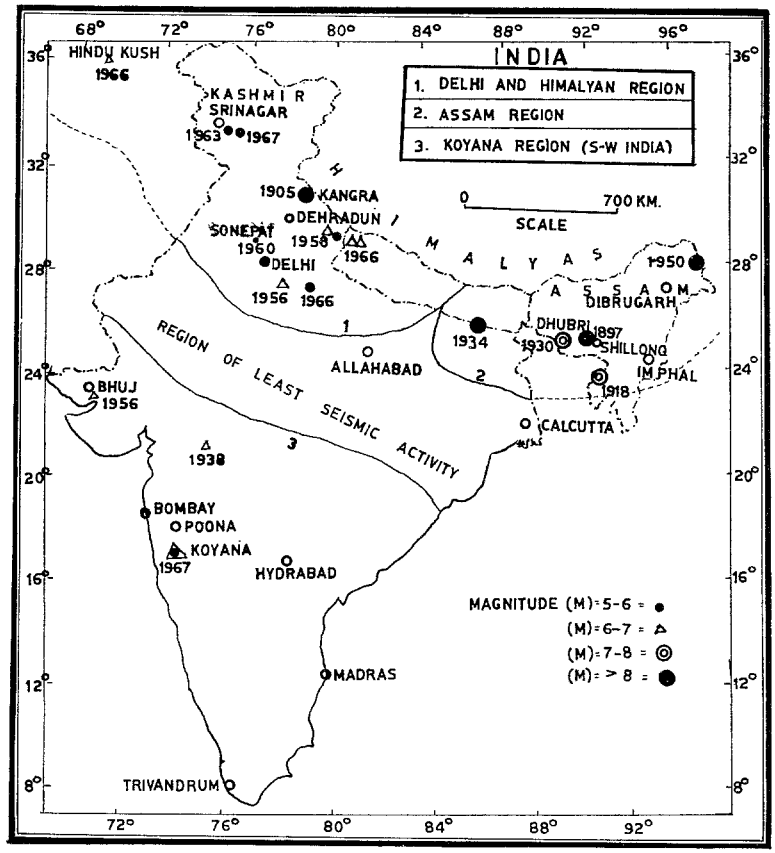

Figure 1
Indian Seismic Regions and Epicentres of Significant Indian Earthquakes ($M > 5$), 1897–1967

2. *Frequency Magnitude and Energy of Earthquakes*

Frequency and magnitude of an earthquake is related statistically in a peculiar manner for a given seismic domain. However, this relationship holds good for the world at large and even for the limited areas which have been studied so far. The relationship [6] is

$$\log_{10} N = a - b\,M \tag{i}$$

where N is the number of shocks of magnitude M per unit time, a and b are constants which differ from one seismic region to another. The values for Delhi and Himalayan region, Assam region and Koyana region have been taken as $a=4.7$, $b=0.59$; $a=4.62$, $b=0.74$ and $a=5.3$, $b=0.18$ respectively. The number of events N have been found for various values of M by taking the above constants values and the results are shown in Fig. 3.

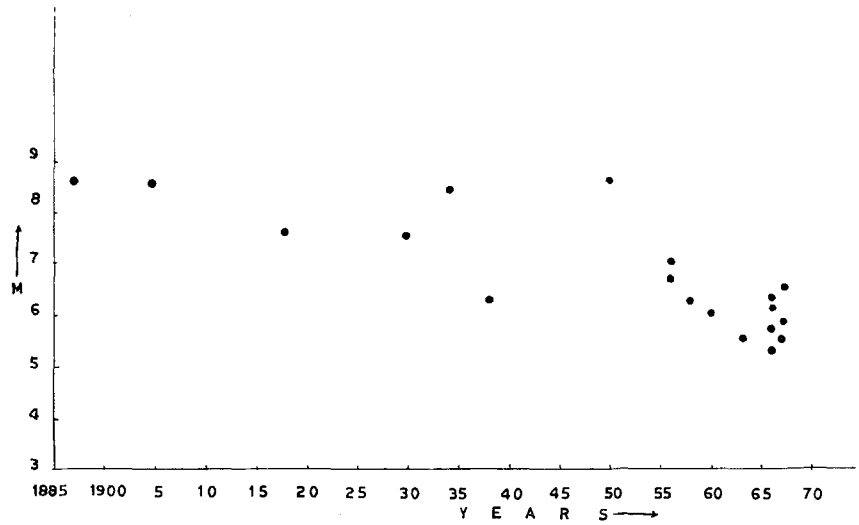

Figure 2
Distribution of Earthquake magnitudes in different years

The total energy E (in ergs) released during an earthquake is associated with magnitude M, empirically [6] by

$$\log E = 11.4 + 1.5\, M. \tag{ii}$$

The energy of important Indian earthquakes ($M > 5$) during last 70 years has been calculated by the well-known above formula (ii) and is shown in Fig. 4.

The distribution of Indian earthquakes ($M > 5$) has also been shown in Fig. 2. It appears from the figure that the number of earthquakes after 1955 are increasing having considerable magnitudes.

3. *Earthquake Occurrence Law*

After plotting the number of events N versus Log E past earthquakes on semilog paper (Fig. 5), the following earthquake occurrence law has been developed,

$$\log N = p + q \log E \tag{iii}$$

where p and q are constants. The coefficient q remains almost the same for all seismic regions but the value of p depends upon the seismicity of a region. This law is practically the same for all other seismic zones of the world. The values of p and q for Indian regions have been calculated and these are

1. Delhi and Himalayan region: $p = 9.17$, $q = -0.39$
2. Assam region : $p = 9.70$, $q = -0.49$
3. Koyana region : $p = 11.45$, $q = -0.54$

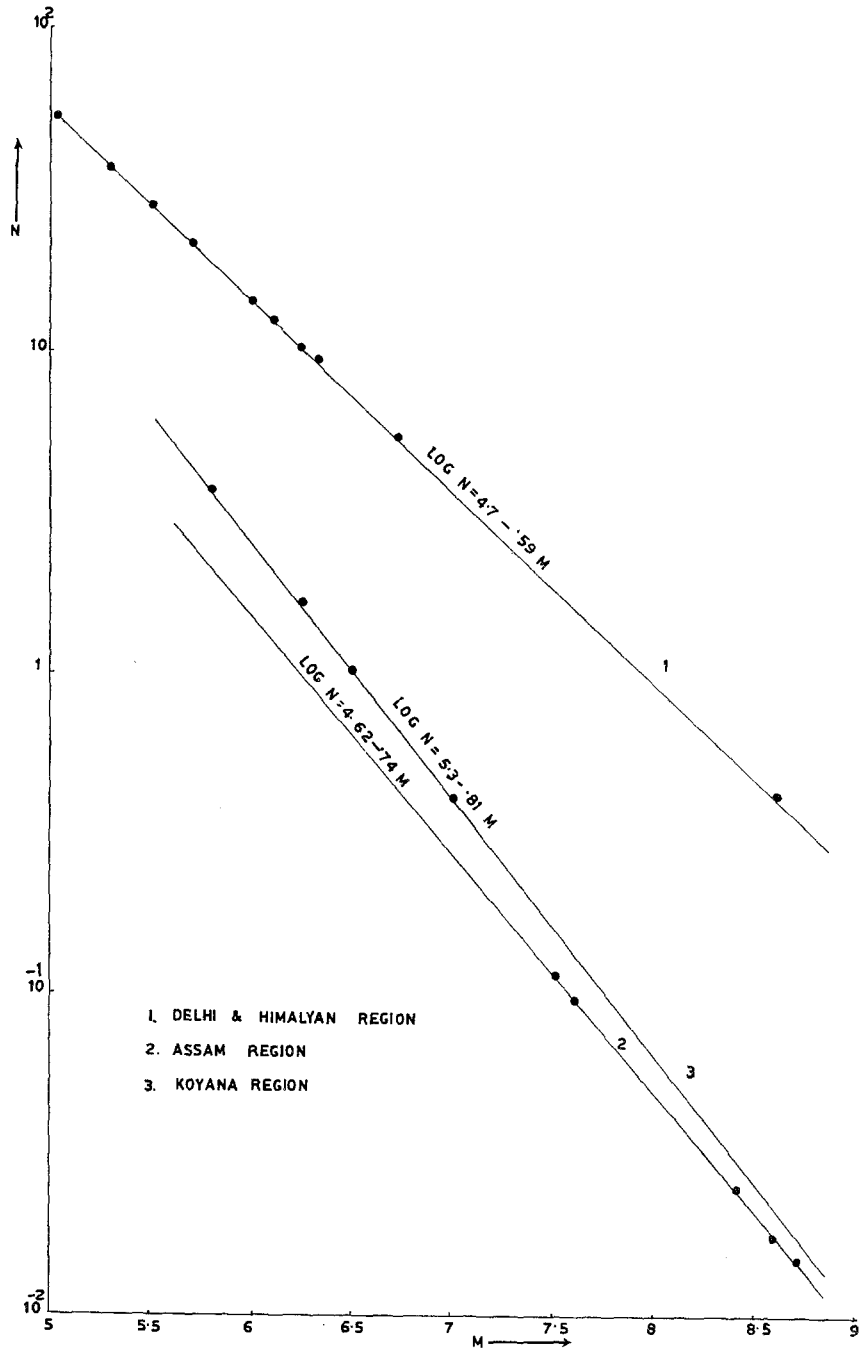

Figure 3
Representation of frequency-magnitude of significant Indian earthquakes

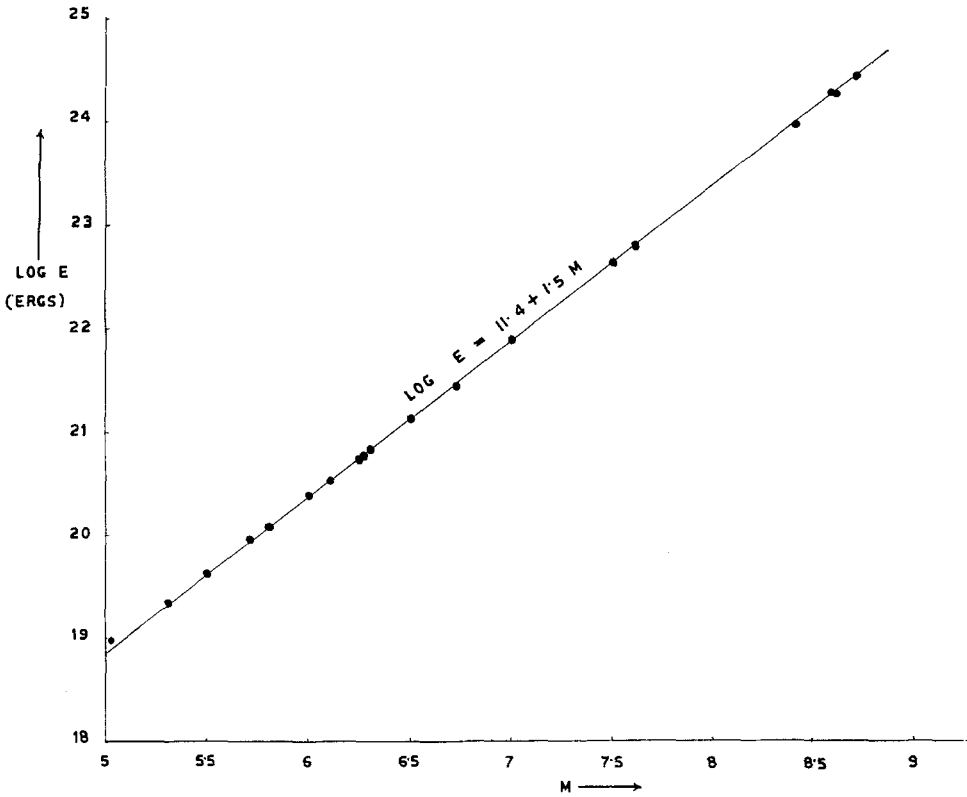

Figure 4
Representation of energy-magnitude of significant Indian earthquakes

Thus the average value of coefficient q is about -0.47, but the values of p are varying considerably as the seismicity for all the three regions is not the same.

4. *Discussion*

A statistical analysis of significant Indian earthquakes during the last seventy years has been made. The earthquakes with magnitude (M) greater than five have been considered. The distribution of earthquake magnitudes with time shows (Fig. 2) clearly that the seismic activity in Indian regions has enhanced considerably during last fifteen years. The earthquakes that occurred during this period are having considerable magnitudes ($M>5.5<7$). Delhi-Sonepat and Koyana regions are of special interest. The earthquakes are frequently occurring in these areas. Very recently Koyana region (south-west India) has been rocked by earth-tremors of moderate to mild intensity (April 13, 1969; 1525 GMT).

The Himalayan as well as the Assam regions have felt severe shocks occasionally. The recurrence period for Assam region is about 45 years for an earthquake of magnitude 8.5 .

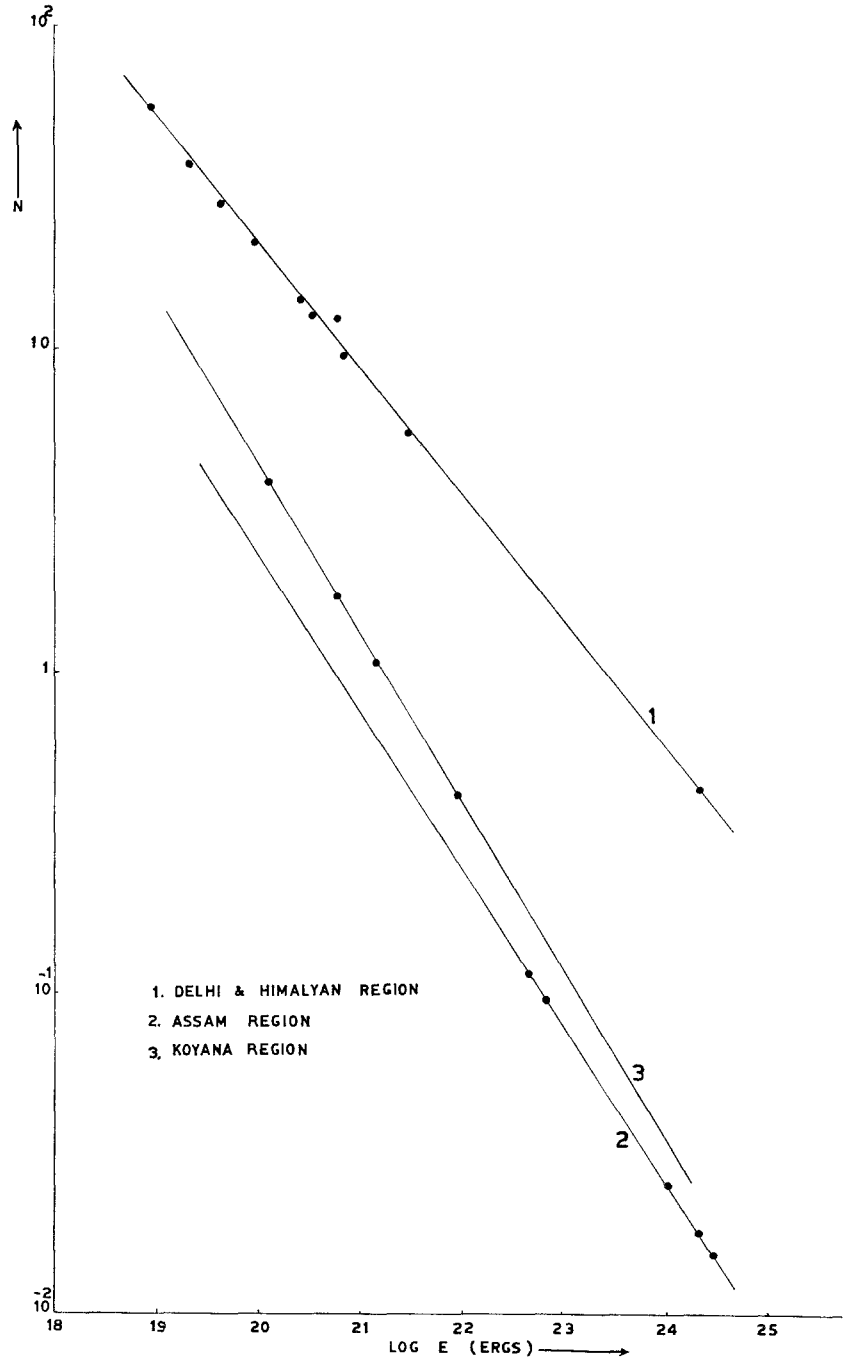

Figure 5
Relationship between frequency and energy of Indian earthquakes

The results obtained are quite satisfactory. The numerical value for q is about -0.47 whereas that of p varies considerably from one region to another. But for each individual region it is more or less constant. The recurrence period for an earthquake of magnitude 8.4 in south-west India (especially Koyana region) is about 35 years as found by frequency-energy analysis for the area.

5. *Conclusion*

Statistics of past Indian earthquakes reveals that some of the seismic zones are gaining momentum as the time is passing on. Specially, area around Delhi and Sonepat and some parts of south-west India are definitely being active. However, on the basis of past earthquake data it is clear that there are no regions in India where the earthquake problem can completely be ignored.

The frequency-magnitude and energy-magnitude relationships have facilitated in developing an other earthquake occurrence law for earthquakes. The authors have found quite fit values of two constants p and q for Indian seismic regions. The value of constant $q(=-0.47)$ agrees well with that found by India Meteorological Department [7].

6. *Acknowledgements*

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REFERENCES

[1] B. GUTENBERG and C. F. RICHTER, *Earthquake magnitude, intensity, energy and acceleration*, Bull. Seism. Soc. Am. *32* (1942), 163–191.
B. GUTENBERG and C. F. RICHTER, second paper, Bull. Seism. Soc. Am. *46* (1956), 105–145.
[2] M. BÅTH, *The relation between magnitude and energy of earthquakes*, Trans. Am. Geophys. Union *36* (1955), 861–865.
[3] B. GUTENBERG, *The energy of earthquakes*, Quart. Journ., Geol. Soc. London *112* (1956), 1–14.
[4] A. S. FURUMOTO, *Seismicity of Hawaii, Pt. I, Frequency energy distribution of Earthquakes*, Bull. seism. Soc. Am. *56* (1966), 1–12.
[5] R. BURRIDGE and L. KNOPOFF, *Model and theoretical seismicity*, Bull. Seism. Soc. Am. *57* (1967) 341–371.
[6] C. F. RICHTER, *Elementary Seismology* (W. H. Freeman and Co., San Francisco 1958), 1–768.
[7] A. N. TANDON and H. M. CHAUDHURY, *A report on the seismicity studies by the India Meteorological Dept.*, Third Symp. on Earthquake Engg., University of Roorkee, 4–6 Nov. 1966 (1966), 1–6.

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