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550.341 (.235.24)

Magnitude, intensity and radius of perceptibility relations for the earthquakes originating from Himalayan regions of north India

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ABSTRACT. The paper presents various relations between magnitude, intensity, radius of perceptibility and radius of epicentral intensity, using the data of destructive earthquakes which had originated from Himalayan regions of north India. On the basis of this study, a nomogram has been prepared to convert one parameter into another.

1. Introduction

The main aim of the present study is to make an immediate assessment of the magnitude or intensity or radius of perceptibility of an earthquake from the nomogram on the lines of Gutenberg and Richter (1956) if any one of the above parameters is known. Such a study is of paramount importance to geologists, seismologists and engineers who face the public and press immediately after occurrence of a great event.

The region chosen for this study is Himalayas. This is a zone of recent folding and fracture and is, therefore, very complex geologically. Many damaging earthquakes as listed in Table 1 occurred in this region. A detailed study of the above parameters has been done in the present paper.

2 Data

16 earthquakes of shallow to normal depth from the period 1897 to 1975, the details of which were available in terms of magnitude, intensity, mean radius of perceptibility and mean radius of epicentral intensity have been selected for the present study. For all practical purposes the magnitude from body waves and the intensity in Modified-Mercalli scale as detailed in Table 1 have been used. The earthquake data in Table 1 excluding intensity, mean radius of perceptibility and radius of maximum intensity have been taken either from Richter (1958), Gutenberg and Richter (1935) or from U.S.C.G.S. The intensity, mean radius of perceptibility and radius of maximum intensity have been taken from different sources, the references of which are given in Table 1.

3 Relation

3.1. *Magnitude & Intensity*—Magnitude is the measure of the size of an earthquake while intensity is the measure of the destruction caused by an earthquake at a place and is therefore variable. It will be maximum around the epicentre and depends upon the magnitude, depth of the focus and the intervening ground. Loose and un-consolidated ground experiences more intensity than the solid foundation. The magnitude and epicentral intensity (maximum intensity) relation has been drawn (Fig. 1) from 15 earthquakes. Magnitude ranges from 5·7 to 8·7 and the intensity from 5 to 12. The linear relation is given below:

$$M = (3{\cdot}09 \pm 0{\cdot}54) + (0{\cdot}49 \pm 0{\cdot}02)\, I \qquad (1)$$

3.2. *Magniude & radius of perceptibility*—Perceptibility of an earthquake depends not only on the magnitude alone but on the focal depth and on the surrounding structure as well. The magnitude *vs* the logarithm of mean radius of perceptibility has been plotted (Fig. 2a) from 13 earthquakes. The relation may be represented by the following linear equation :

$$\log r = (0{\cdot}85 \pm 0{\cdot}36) + (0{\cdot}26 \pm 0{\cdot}01) M \qquad (2)$$

where magnitude varies from 6·0 to 8·7 and the mean perceptibility from 160 to 1400 km.

3.3. *Magnitude & radius of epicentral intensity*—Like the intensity and radius of perceptibility, the radius of epicentral intensity (maximum intensity depends upon the focal depth of an earthquake and the local geology. Magnitude *vs* logarithm of mean epicentral intensity has been plotted (Fig. 2b)

TABLE 1

S. No.	Date	Epicentre Lat. (°N)	Epicentre Long. (°E)	Mag.	I	r	r_o	Source of data
1	1897, Jun 12	26·0	91·0	8·7	XII	1400	180	Mithal and Srivastava (1962), Richter (1958) and Tandon (1962)
2	1905, Apr 4	32·7	76·5	8·6	XI	1160	90	Tandon (1962) and Krishnaswamy (1962)
3	1918, Jul 8	24·1	91·8	7·6	IX	820	15	Tandon (1962)
4	1930, Jul 3	25·8	90·2	7·1	IX	540	—	Mithal and Srivastava (1962)
5	1931, Aug 27	29·8	67·3	7·4	VIII	540	—	Seismol. Bull., India met. Dep.
6	1934, Jan 15	26·5	86·5	8·4	X	1380	35	Tandon (1962)
7	1935, May 30	29·6	66·5	7·6	IX	290	30	Do.
8	1945, Jun 22	32·5	76·0	6·5	VI	160	10	Krishnaswamy (1962)
9	1950, Aug 15	28·5	96·5	8·7	X	1250	48	Tandon (1962)
10	1956, Oct 10	28·2	77·5	6·8	VIII	—	5	Do.
11	1960, Aug 27	28·2	77·4	6·0	VII	—	10	Do.
12	1966, Feb 7	29·8	69·7	6·8	—	484	—	Seismol. Bull., India met. Dep.
13	1966, Jun 27	29·7	80·9	6·1	VIII	360	—	Do.
14	1967, Feb. 20	33·69	75·28	5·7	VI	—	10	Do.
15	1974, Dec 28	35·1	72·9	6·0	V	350	7	USCGS
16	1975, Jan 19	32·45	78·43	7·0	IX	* 450	16	Singh *et al.* (1975)

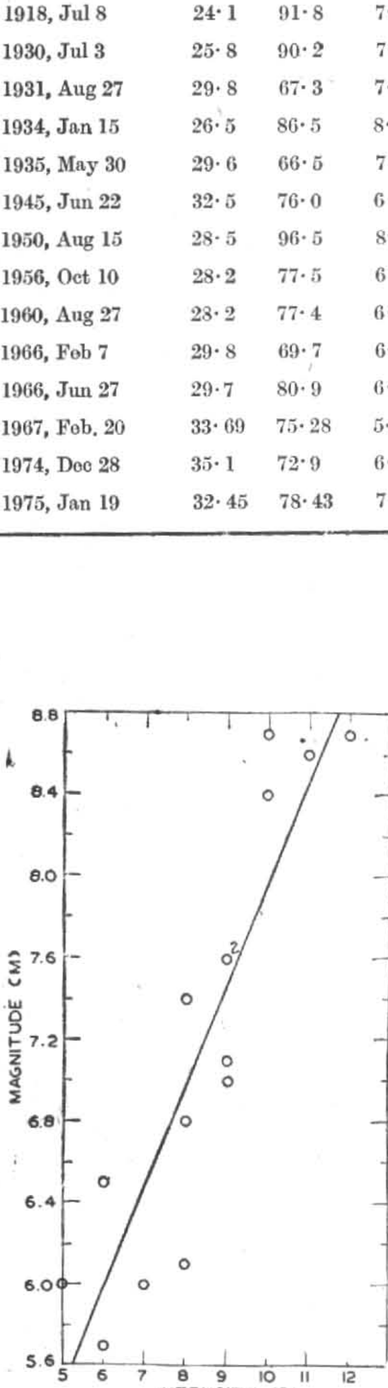

Fig. 1. Magnitude intensity relation

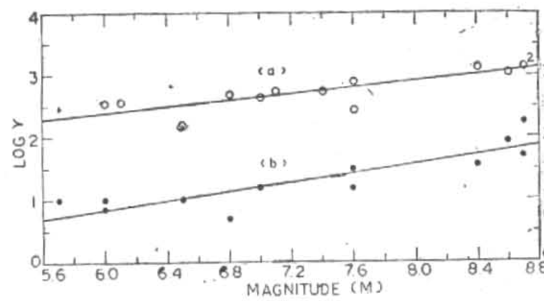

Fig. 2. Magnitude log r and log r_o relation

TABLE 2

Comparison of magnitude and intesity relations

Intensity (M.M.)	Magnitude Present study	Magnitude Gutenberg and Richter (1956)
1	3·58	1·67
2	4·07	2·33
3	4·56	3·00
4	5·04	3·67
5	5·52	4·34
6	6·01	5·00
7	6·50	5·67
8	6·98	6·34
9	7·47	7·00
10	7·96	7·67
11	8·44	8·34
12	8·93	9·00

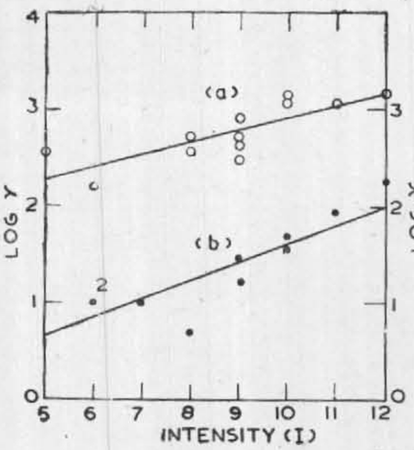

Fig. 3. Intensity, log r and log r_0 relation

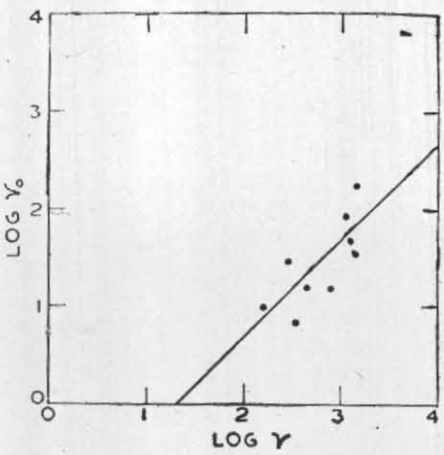

Fig. 4. Log r-log r_0 relation

from 12 earthquakes data and the linear relation may be represented as follows :

$$\log r_0 = (-1{\cdot}32 \pm 0{\cdot}50) + (0{\cdot}36 \pm 0{\cdot}02)M \quad (3)$$

where magnitude varies from 5·7 to 8·7 and the radius of epicentral intensity from 5 to 180 km.

3.4. *Intensity & radius of perceptibility*—Radius of perceptibility increases with the focal depth and *vice versa.* Deep earthquakes are felt over a much wider area than the shallow earthquakes of the same intensity because the maximum intensity is less in proportion to the total energy of the earthquake owing to the greater depth of the focus. Both the intensity and perceptibility increase on loose soils and decrease on consolidated hard rocks. Intensities have been plotted *vs* logarithms of the mean radius of perceptibility (Fig. 3 a) from 12 earthquakes data and the relation may be represented by the following linear equation :

$$\log r = (1{\cdot}65 \pm 0{\cdot}23) + (0{\cdot}13 \pm {\cdot}01)I \quad (4)$$

where intensity varies from 5 to 12 and perceptibility from 160 to 1400 km.

3.5. *Intensity & radius of epicentral intensity*—Unlike the radius of perceptibility, the radius of epicentral intensity decreases with the focal depth of the earthquake. Intensities have been plotted *vs* logarithm of mean radius of epicentral intensity from 12 earthquakes (Fig. 3 b) and the relation may be represented by the following linear equation :

$$\log r_0 = (-0{\cdot}30 \pm 0{\cdot}28) + (0{\cdot}19 \pm 0{\cdot}01)\, I \quad (5)$$

where intensity varies from 5 to 12 and the corresponding radius of epicentral intensity from 5 to 180 km.

3.6. *Radius of perceptibility & radius of epicentral intensity*—It has been observed that perceptibility of an earthquake has a correlation with the radius of epicentral intensity and so the logarithm of mean radius of epicentral intensity has been plotted *vs* the logarithm of mean radius of perceptibility for 9 sets of observations (Fig. 4) and the following linear relation has been obtained :

$$\log r_0 = (-1{\cdot}28 \pm 0{\cdot}93) + (0{\cdot}98 \pm 0{\cdot}12)\log r \quad (6)$$

where r_0 varies from 7 to 180 km and r from 160 to 1400 km.

With the help of Eqns. (1) and (2) a nomogram has been prepared (Fig. 5) linking magnitude (M) with the epicentral intensity (I) and the mean radius of perceptibility (r) and this may be used for converting one parameter into another.

The results of this study have been compared with that of Gutenberg and Richter (1956) for California region (Tables 2 and 3) and it has been observed that M-log r relations for both the regions (California and Himalayas) do not show enough variations. M-I relations, however, differ for lesser magnitude values and as the magnitude increases, this difference decreases. This shows that for great events the regional variations produce little effect on the epicentre intensity.

4. Discussion of the results

Most of the earthquakes studied in this region have elliptical isoseismals which indicate that the energy distribution from the source is not uniform or in other words the structure is not perfectly homogeneous but of complex nature which is generally found in Himalayan regions of north India. In many cases the axes of the elliptical isoseismals were found to be more elongated towards south and this may be interpreted as being the result of

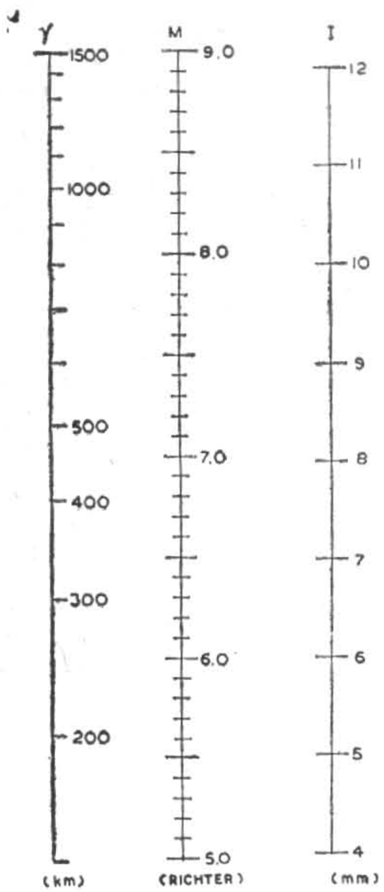

Fig. 5. Conversion nomogram for M, I and r

the *M*-discontinuity dipping towards north. As a result of this a particular earthquake has done more damage at a given distance in the south than that at the same distance to the north.

Such a study which depends upon the macroseismic evidences may not be very much accurate, however, it gives a clear estimate of earthquake parameters, generally required by scientists, engineers and seismologists to satisfy the public and

TABLE 3

Comparison of magnitude and radius of perceptibility

Radius of percep-tibility (km)	Magnitude	
	Present study	Gutenberg and Richter (1956)
100	4·47	4·60
200	5·63	5·74
300	6·31	6·41
400	6·80	6·89
500	7·17	7·26
600	7·48	7·56
700	7·74	(7·81)
800	7·96	(8·03)
900	8·16	(8·22)
1000	8·34	(8·40)
1100	8·50	(8·56)
1200	8·64	(8·70)
1300	8·78	(8·83)
1400	8·90	(8·95)
1500	9·02	(9·07)

Note – Values in the bracket are theoretical values

the press. So by making use of nomogram, it has become possible now to get a first hand information regarding the destruction which an earthquake of particular size may cause. However, in a vast country like India which is facing from the north the mighty Himalayas of recent geological origin which are in a state of adjustment and the southern part of India which is called the shield against the major earthquakes, the one conversion nomogram may not be applicable to both the regions.

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