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SEISMICITY OF NORTH-EAST INDIA

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INTRODUCTION

The main aim of the present paper is to study the recurrence pattern of the earthquakes in this region which is highly complex geologically and where many disastrous earthquakes occurred in the past. Among them, Assam earthquakes of 1897 and 1950 and Bihar earthquake of 1934 as located in Fig. I are worth mentioning.

The causes of such phenomena presumably lie in the geological and tectonic set up of this region.

The study of seismic activity is of paramount importance as it affects the government economy on engineering work at a place.

Bath (1952) was the first to define seismicity as the total energy released per unit area per unit time. Later on, St. Amand (1956) expressed it quantitatively as the sum of energy released by all earthquakes occurring in an area in a given time divided by the area and time as follows:

$$S=\frac{K}{AT}\int_{A}\int_{T} J\, dA\, dT \qquad \ldots(1)$$

where S=Specific seismicity or tectonic flux.

K=Constant

A=Area for which seismicity is to be determined.

T=Time period of the observation.

J=Energy released by earthquakes in ergs.

As the distribution of epicentres is a discrete case, the expression (1) may also be written as

$$S_J=\frac{K}{AT}\sum_{A}\sum_{T} J_i \qquad \ldots(2)$$

The first essential step to study a region is to see the effect of the past earthquakes. Table (1) therefore gives a list of all the earthquakes of historic times having magnitudes above 7.0 which occurred in this region. Some of them were very destructive and felt widely.

THE DATA

A very great earthquake of magnitude 8.7 occurred in this region in the year 1950 followed by a large number of after shocks and so the data has been collected from 1951 to study the future seismic activity of this region, as it is a well known fact that the seismicity of a region changes with the time. The earthquakes from Tibet and China were not included in this study. The epicentre, magnitude, and depth of 177 earthquakes from the period 1951 to 1971 have been collected from I.S.C. Edinburg, U.S.C.G.S., I.S.S. or B.C.I.S. Whenever the depth and magnitude of a shock was not determined by any of these agencies they were collected from the other near-by reporting stations such as Shillong, Moscow, Peking etc. All the earthquakes have been plotted magnitude-wise as shown in Fig. 1. In some felt earthquake cases when the magnitude was not determined by any reporting agency, its assessment was made by the macroseismic evidences gathered. Body wave magnitude. (MB) was used for all practical purposes. It may be seen from Fig. 1, that the seismic activity in the regions where major earthquakes occurred in the past has subsided. Only Manipur-Burma Border region is having cluster

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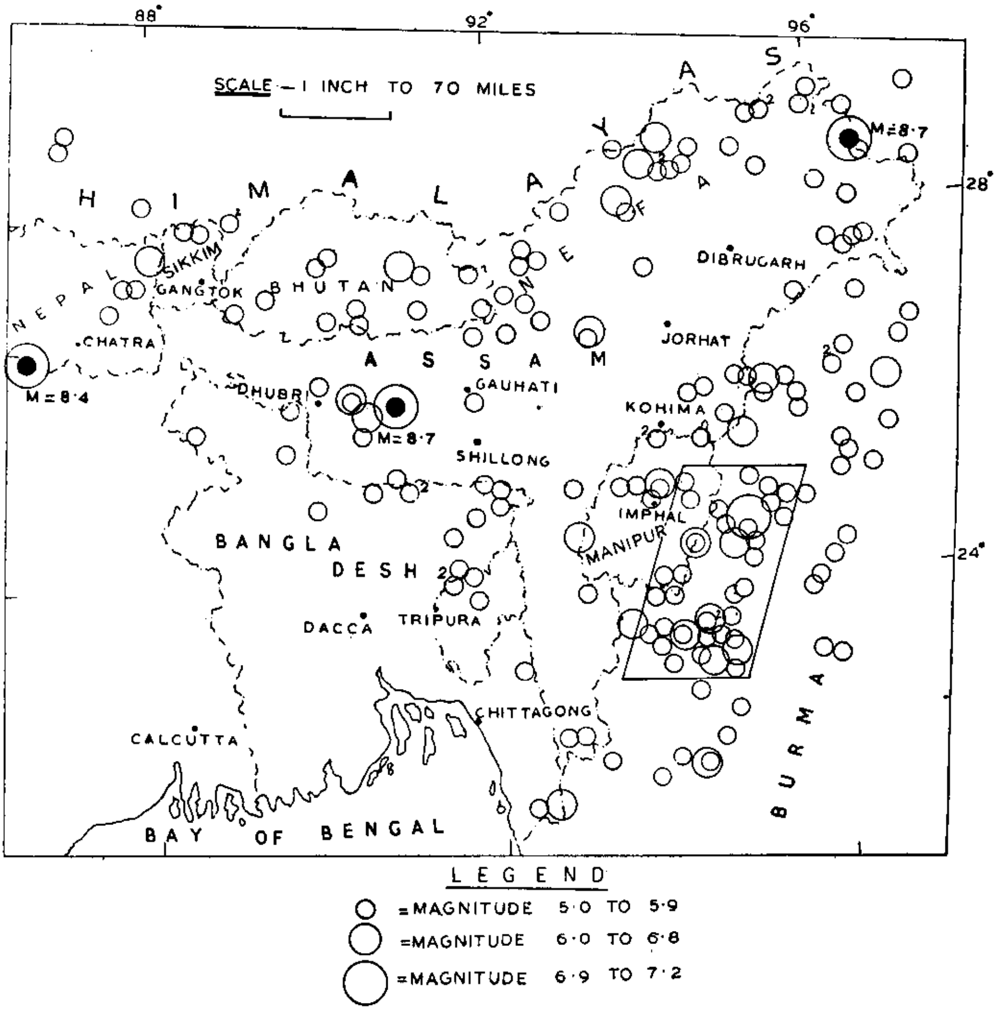

Figure 1. Earthquake epicentres for North-East India and Burma Border Region from 1951 to 1971 alongwith a few great earthquakes of historic times

of earthquake epicentres, which shows that sufficient strain is accumulating in its interior and at any time the equilibrium may be disturbed. The author, therefore, has made a special study of this region in the present paper.

MANIPUR-BURMA BORDER REGION

I. Spatial distribution of earthquakes.

Several tectonic features can be resolved with the depth distribution of earthquakes. The depth distribution of the epicentres for India–Burma border region gives a clear picture. There seems to be several faults in this zone at different depths.

The main fault lies between lat. 23.0°–24.5° N and long. 93.5°–95.0° E at a depth of 65±5 Km in the Manipur-Burma Border region as shown in Fig. 2. This is one of the

TABLE I

PARAMETERS OF EARTHQUAKES OF MAGNITUDES GREATER THAN 7.0 IN NORTH-EAST INDIA FROM 1897 TO DATE.

Serial Number	Date	Origin Time (G.M.T)	Epicentre Lat °N	Epicentre Long °E	Magnitude
1.	1897, June 12	110600	26.0	91.0	8.7
2.	1918, July 8	102207	24.1	91.8	7.6
3.	1923, Sept 9	220343	25.5	91.5	7.1
4.	1930, July 2	210342	25.8	90.2	7.1
5.	1934, Jan. 15	084318	26.5	86.5	8.4
6.	1941, Jan. 21	023015	27.5	92.5	7.1
7.	1943, Oct. 23	172316	27.5	93.5	7.3
8.	1947, July 29	134322	28.5	94.0	7.9
9.	1950, Aug. 15	140930	28.5	96.5	8.7
10.	1954, March 21	234205	24.5	95.0	7.2

major faults in this region and appears to be dipping downwards and joining with another equally potent fault between lat. 23.0°–25.0°N and long. 94.0°–95.0°E at a depth of 100 ± 10 Km. Below this there rests another fault at a depth of about 150 Km. near lat. 23.5°–25.0°N and long. 94.5°–95.5°E. So from the figure 2, it is quite clear that this entire border (India-Burma border region) is a multifaulted zone. Between each active fault zone there lies the nonactive zones also as may be seen from Fig. 2. The faults are dipping towards South-East parallel to the Burmese arc having the East-ward slopping.

II. Recurrence rate curve.

Every group of homogeneously faulted structure of definite competency and size has a definite ceiling of earthquake magnitudes. Accordingly the observed number of earthquakes N(M) which occur in a given region during a certain time interval and which possess magnitude M or above, generally fit an empirical relation given by Gutenberg and Richter (1954) of the form

$$\log N(M) = a - b\,M \qquad \ldots(3)$$

or

$$b = -\frac{d\{\log N(M)\}}{dM} \qquad \ldots(4)$$

where N(M)=Number of earthquakes of magnitude M or above, 'a' and 'b' are constants.

The constant 'a' gives the relative seismicity of the region and depends upon the magnitude interval and the unit chosen for the area. The constant 'b' which represents

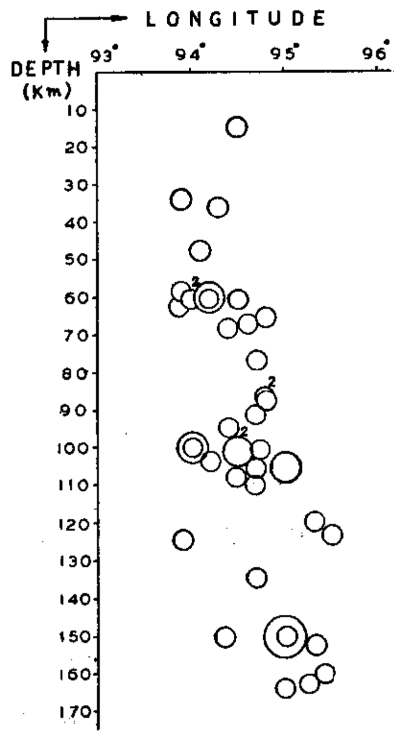

Figure 2. Longitude versus depth distribution of earthquakes in Manipur-Burma border region

the slope of the fitted straight line lies between 0.5 and 1.5 and is independent of the geological conditions. Low value of 'b' represents the lower rate of occurrence of and reporting of small shocks while high values of 'b' are due to low rate of occurrence of large events.

A cumulative magnitude versus earthquake recurrence curve for Manipur-Burma border region has been plotted in Fig. 3 from 42 earthquakes for 21 years period. The magnitudes range from 5.0 to 7.2. The equation of the fitted straight line is given below

$$\text{Log } N(M) = 4.04 - 0.75 \text{ M} \quad \ldots(5)$$

The expected time in years for recurrence of earthquakes of various magnitudes have been determined as shown in **Table II.** Tandon et al. (1968) determined the values of 'a' and 'b' constants for Himalayas as 4.10 and 0.98 respectively.

III. Direction of Faulting

It is a well known fact that the geological structures move abruptly along tectonically homogeneous active fault-zones not simultaneously but alternatively in different places of the zones and at different depths. Consequently, the direction of faulting in a major earthquake reveals the future propagation of the rock-fracture if the strain is not completely released from its interior. The fracture propagates in a regular manner in a definite direction causing the accumulation of energy.

An earthquake of magnitude 7.2 occurred on Manipur-Burma border region on 22 March, 1954. It was of the highest magnitude known to have occurred in this region and was strongly felt at many places. Some damage to the structure was also noticed.

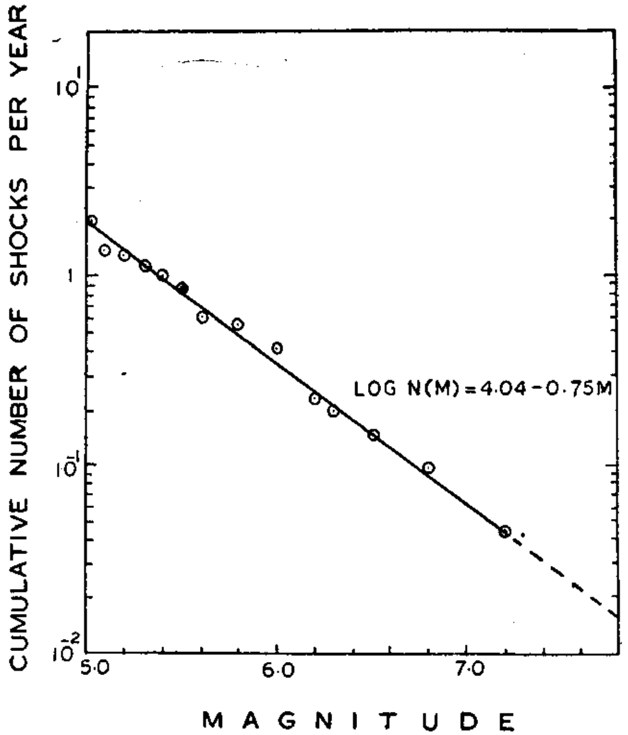

Figure 3. Cumulative sum of earthquakes versus magnitudes curve for Manipur-Burma border region

The direction of faulting in this earthquake was studied by Tandon and Mukherjee (1956) as shown in Fig. 4 using Byerly's method. The circle A represents the fault plane. The

TABLE II

EXPECTED TIME IN YEARS FOR ONE SHOCK TO OCCUR OF A FIXED MAGNITUDE CLASS

Serial Number	Magnitude	Expected time (years)
1.	5.0 and above	0.51
2.	6.0 „	2.86
3.	7.0 „	16.67
4.	7.2 „	22.94

displacement was along a reverse fault striking N 50°E and dipping to NW at an angle of 60°. The motion was probably in this plane along a line striking N 78°E such that the hanging wall side moved NE and up.

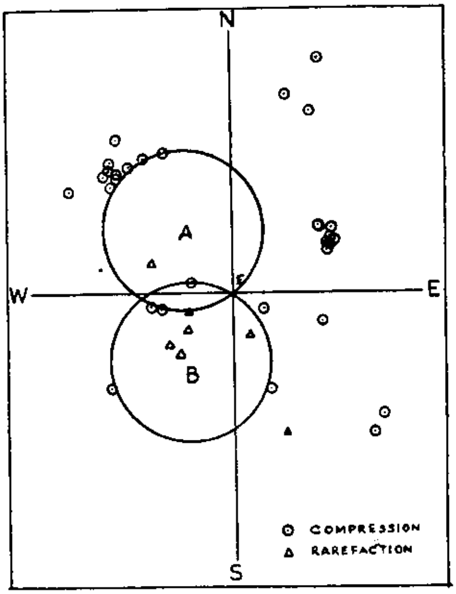

Figure 4. Direction of faulting in Manipur–Burma border earthquake of March 22, 1954 (after Tandon and Mukherjee).

A similar study of focal mechanism was done by Fitch (1970) from two earthquakes originating from India-Burma border region and it was found that in both the cases the mechanisms were consistent with under thrusting on a plane dipping towards North i.e. beneath the Himalayan mountain front. Geological evidence is also there for thrust faulting along Himalayan mountain front.

IV. Discussion and Result

From the earthquakes listed in Table I, it is quite clear that in North-East India there had been a tendency for gaps in the seismic pattern which were subsequently filled in by the great earthquakes. However, during the period under investigation, the seismic activity in the Himalayan mountain belt where three very great earthquakes occurred in the past has considerably slowed down which may be observed from Fig. 1. This current quiescence might be explained as the elastic strain was fully relieved during the very great earthquake of 1950 and has not yet built up again to the breaking point.

From the study of the seismic activity in North-East India, it is concluded that except Manipur-Burma border fault, other faults are nearly dead. As this fault is very young, there is a great probability of the occurrence of a major earthquake in this area. The region is very unstable, specially near the place where Arakanyoma mountain ranges join up with the Himalayan tails extending south-wards. This junction is several kilometers hollow like a nest and presents a special geological feature. The mountains are heavily folded into arcs and look like having been formed by the North-East ward pressure due to the drift of Indian block. The fact about its unstability is further supported by the study of the gravity anomalies in this region. According to Wadia (1965) there is a belt of positive anomalies along Khasi hills where the higher value attained is about 100 milligals and in the surrounding Burma arc there is a belt of negative gravity anomalies upto 75 milligals following the lines of maximum uplift in the hills separating Assam from Burma.

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