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**SEISMICITY AND TECTONICS OF NORTHEAST INDIA AND NORTHERN BURMA**

1. Analysis of seismicity of northeast India and northern Burma has been carried out for the period 1897-2000. Epicentral maps for magnitude 4.0–4.9 (period 1963–2000, nearly 880 events) and magnitude  $\geq 5.0$  (period 1897–2000, nearly 485 events) are presented. The highest seismicity has been observed along the Arakan-Yoma Folded Belt and the Molasse Basin of Burma. This region has experienced 19 events of magnitude  $\geq 7.0$  during the period 1897-2000. The largest number of events of magnitude  $\geq 4.0$  is also located in this region. Other areas that are found to be seismically active include the Shillong Plateau, the central part of eastern Himalaya and the Mishmi Thrust region. It is observed that the seismic zone over Shillong Plateau extends towards the Mikir Hills in NE as well as the Assam valley. A study of aftershocks of great Assam earthquake of 1950 shows that the area of aftershocks extended much beyond the Mishmi/Lohit thrusts up to Tibetan Plateau in the north and Naga Hills in the south.

From seismicity point of view, the northeast India and the northern Burma are one of the most active regions of Asia. The area has experienced two devastating earthquakes in Indian history, the Shillong earthquake of 1897, (magnitude 8.7) and the Assam earthquake of 1950 (magnitude 8.5). In addition, historical earthquakes exceeding intensity IX (RF scale) have taken place at Dhubri (1930), near Darjeeling (1899), Chittagong (1869) and Srimangal (1918). The Arakan-Yoma Folded Belt of northern Burma has experienced earthquake of intensity IX to X at Amarapooora (1839), Kachin (1931) and Sagaing (1946). On account of considerable importance of the region from seismicity point of view, several organisations including NGRI Hyderabad, RRL Jorhat and India Meteorological Department have established seismological observatories in the region. In addition, University of Roorkee and GSI have also established MEQ stations to monitor the seismicity for short periods of time. A brief analysis of seismicity of the region is presented here.

2. The geology and tectonics of the region have been discussed by Brunschweiler (1966) and Evans (1964). The area comprises the following major tectonic units (Fig. 1) :

- (i) Eastern Himalaya
- (ii) Mishmi Block, including Mishmi and Lohit Thrusts
- (iii) Assam Valley

(iv) Shillong Plateau and Mikir Hills

(v) Arakan-Yoma Folded Belt

(vi) Bengal Basin

The geology and Tectonics of different regions is briefly discussed below. A tectonic map of the region after Evans (1964) is shown in Fig. 1. The eastern Himalaya lie between Latitudes  $27^\circ - 29^\circ$  N and Longitudes  $88^\circ - 96^\circ$  E and are composed of Paleozoic, Mesozoic and Tertiary formations. The tectonics of the region is dominated by extensive thrust sheet including the Main Boundary Fault (MBF) and the Crystalline Thrust (CRT), both dipping towards north. The Himalaya folded belt, which has a NE-SW trend takes a sharp turn near  $95^\circ$  E and assumes a strike of NW - SE, in the region known as "Assam Syntaxis". Two prominent thrusts in this region are the Mishmi Thrust and the Lohit Thrust.

The strike of Tertiary Folded Belt changes abruptly near  $27^\circ$  N,  $96.5^\circ$  E, where it continues in the form of Naga Hills, which consists of Tertiary succession ranging in age from Eocene to Paleocene. The Assam-Brahmaputra Valley lies between the eastern Himalaya and the Naga Hills. The Valley has been formed by sediments, which have been brought by the river Brahmaputra and its tributaries. The Shillong Plateau and Mikir Hills consist of Archaean gneisses complex with Proterozoic intracratonic Shillong series. The Mikir Hills lie to the NE of Shillong Plateau and are separated from it by Kopili Fault/Lineament. At the southern edge of Shillong Plateau lies the Dauki Fault, which separates it from the Bengal Basin. To the east of the Bengal Basin lies the Arakan-Yoma Folded Belt of Burma, between  $22^\circ - 27^\circ$  N,  $92^\circ - 94^\circ$  E. The Folded Belt consists of a series of thrusts and thrust sheets. A Flyschtrough (Paleogene) lies over the western side, while the Central Burma Molasse Basin lies to the east of the folded belt, approximately between  $94^\circ - 96^\circ$  E. The Arakan-Yoma Folded Belt extends up to the Naga Hills in the north.

It is apparent from above that large-scale vertical as well as horizontal movements have taken place in the area as a result of collision of the Indian and the Eurasian plates. This has resulted in the formation of the eastern Himalaya as well as Tibetan Plateau to the north, the Mishmi Thrust region in the northeast, the Arakan-Yoma Folded Mountains in the south, the Shillong Plateau in the north, the Assam Valley in between the eastern Himalaya and the Naga Hills. The northward movement of the Indian plate is still continuing as evidenced by appreciable

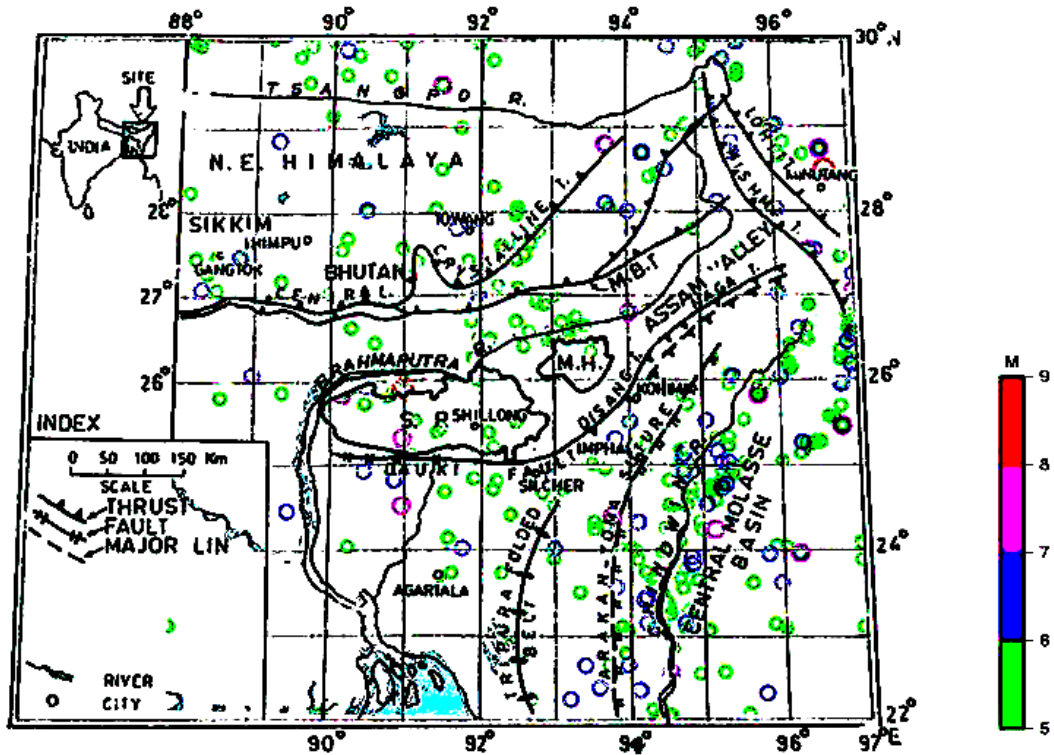


Fig. 1. Tectonic map of NE India and northern Burma (Modified after Evans, 1964). The figure shows the locations of seismic observatories in the region and epicenters of events determined using SEISAN software of magnitude  $\geq 5.0$  for the period 1897-2000

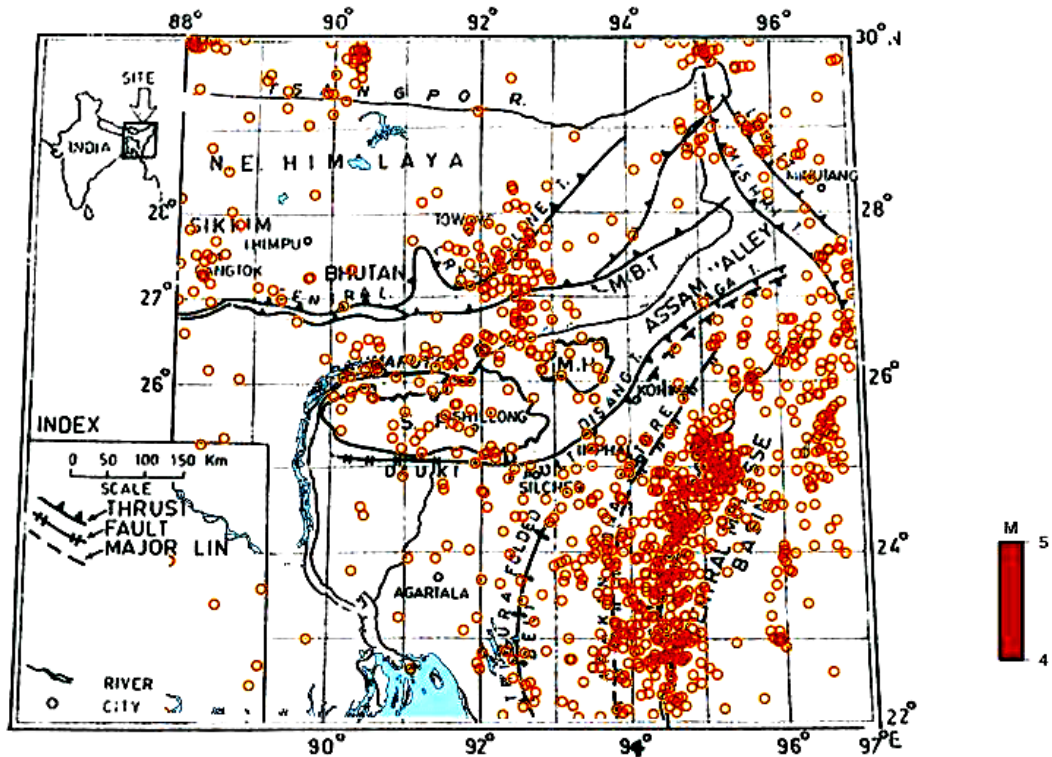


Fig. 2. Epicentral map of the region for magnitude 4.0-4.9 for the period 1963-2000 (by using SEISAN software)

seismicity in all the tectonic units of NE India and northern Burma. A brief analysis of seismicity of the region is presented here.

3. Detailed seismicity of the region has been studied by Tandon (1954), Chaudhary and Srivastava (1976), Geller and Kanamori (1977), Goswami and Sarmah (1982), Verma and Kumar (1987), Mukhopadhyay and Das Gupta (1988), Gupta and Singh (1989), Kayal and De (1991), Verma (1991), Gupta *et al.* (1993), Verma *et al.* (1993), Kayal (1996, 2001), Goswami. (2001) and several others. Historical seismicity of the region for the period 1897 to 2000 is shown in Fig. 1 and the epicentral parameters of the events of magnitude  $\geq 7.0$  during the period of 1897-2000 are shown in the Table 1.

The most devastating earthquake in Indian history (Magnitude 8.7) took place over Shillong Plateau at  $26.0^\circ$  N,  $91.5^\circ$  E in 1897. The maximum intensity of this earthquake was XII and the area of damage extended for 300 km in east–west direction and 200 km towards north. The Shillong Plateau is even now one of the most active areas of this region, having experienced a major earthquake in 1923 near Dauki Fault and the 1930 near Dhubri (Fig. 1 and Table 1). The Burmese Folded Belt including the Arakan-Yoma and the Burmese Molasse Basin is the most active area of this region. Here several events of magnitude greater than 7.0 have taken place in 1908, 1918, 1926, 1927, 1938 and 1946. The Assam Valley to the east of Mikir Hills has experienced an event of magnitude 7.2 in 1943. In eastern Himalaya an event of magnitude 7.7 has taken place near the Crystalline Thrust in 1947. In Bengal Basin an event of magnitude 7.6 took place at Srimangal in 1918. One of the most devastating earthquakes in Indian history (magnitude 8.5) took place in August 1950 to the northeast of Lohit Thrust. Aftershocks of this earthquake extended over a large area ranging from  $26^\circ$  to  $30^\circ$  N &  $93.5^\circ$  to  $97^\circ$  E during the period 1950-51. These included the Naga Thrust region in the south, the Mishmi and Lohit thrusts as well as the NE Himalaya.

Epicentral locations of the events of magnitude 5.0-5.9, 6.0-6.9, 7.0-7.9 and 8.0-8.9 for the period of 1897-2000 are shown in the Fig. 1. The figure shows the epicentral locations of nearly 320 events of magnitude 5.0–5.9, nearly 145 events of magnitude 6.0-6.9, 17 events of magnitude 7.0-7.9 and 2 events of magnitude 8.0-8.9 for the period 1897-2000. It is apparent that the Burmese Folded Belt to the east of Arakan-Yoma Suture including northern Burma is the most active region. However, other regions including the Assam Valley to the NW of Mikir Hills, the Himalaya Thrust regions, the Mishmi Thrust region as well as the Shillong Plateau are also areas of

TABLE 1

List of earthquakes of magnitude 7.0 & above during the period 1897-2000

S. No.	Year	MMDD	HHMM	SS.S (UTC)	Lat. (°N)	Long. (°E)	Depth (km)	Mag.
1	1897	612	11 6	0.0	25.900	91.000	0.0	8.7
2	1906	831	1457	30.0	27.000	97.000	100.0	7.0
3	1908	1212	1254	.0	26.500	97.000	0.0	7.5
4	1915	12 3	239	19.0	29.500	91.500	0.0	7.1
5	1918	7 8	1022	7.0	24.500	91.000	0.0	7.6
6	1923	9 9	22 3	42.0	25.300	91.000	0.0	7.1
7	1930	7 2	21 3	34.0	25.800	90.200	0.0	7.1
8	1931	127	20 9	21.0	25.400	96.800	0.0	7.6
9	1932	814	439	39.0	25.800	95.700	120.0	7.0
10	1938	816	427	55.0	22.500	94.500	65.0	7.3
11	1943	1023	1723	17.0	26.800	94.000	0.0	7.2
12	1946	912	1517	17.0	23.900	96.200	0.0	7.5
13	1947	729	1343	20.0	28.800	93.700	0.0	7.7
14	1950	815	14 9	28.5	28.460	96.660	0.0	8.5
15	1950	816	641	57.0	28.700	96.600	0.0	7.0
16	1950	826	633	6.0	26.800	95.000	0.0	7.0
17	1950	913	11 7	27.0	27.500	96.400	0.0	7.0
18	1954	321	2342	17.0	24.200	95.100	0.0	7.3
19	1957	7 1	1930	22.0	24.380	93.760	41.0	7.2

high seismic activity. Fig. 2 shows the epicentral locations of nearly 880 events in the region for magnitude 4.0 - 4.9 (period 1963 - 2000). The following major features are noticeable:

(i) The Arakan–Yoma Folded Belt to the east of  $92^\circ$  E is the most active region. The seismicity along this arc extends up to Naga Thrust in the north and extends from  $92^\circ$  to  $97^\circ$  E in the east. The seismicity has a north-south trend in the south, which changes to northeast-southwest in the north in accordance with the trend of the Naga Thrust.

(ii) The Shillong Plateau shows a high seismicity, which extends towards Mikir Hills in northeast and towards north over the Assam Valley.

(iii) The seismicity over the Mikir Hills extends towards Himalaya beyond the Main Boundary Fault in northwesterly direction.

(iv) Seismicity in eastern Himalaya is concentrated near Sikkim in the west, near long.  $92^\circ$  -  $94^\circ$  E in the central part and near the Mishmi Thrust region in the east.

(v) Considerable seismicity is observed over the Mishmi Thrust and Lohit Thrust region.

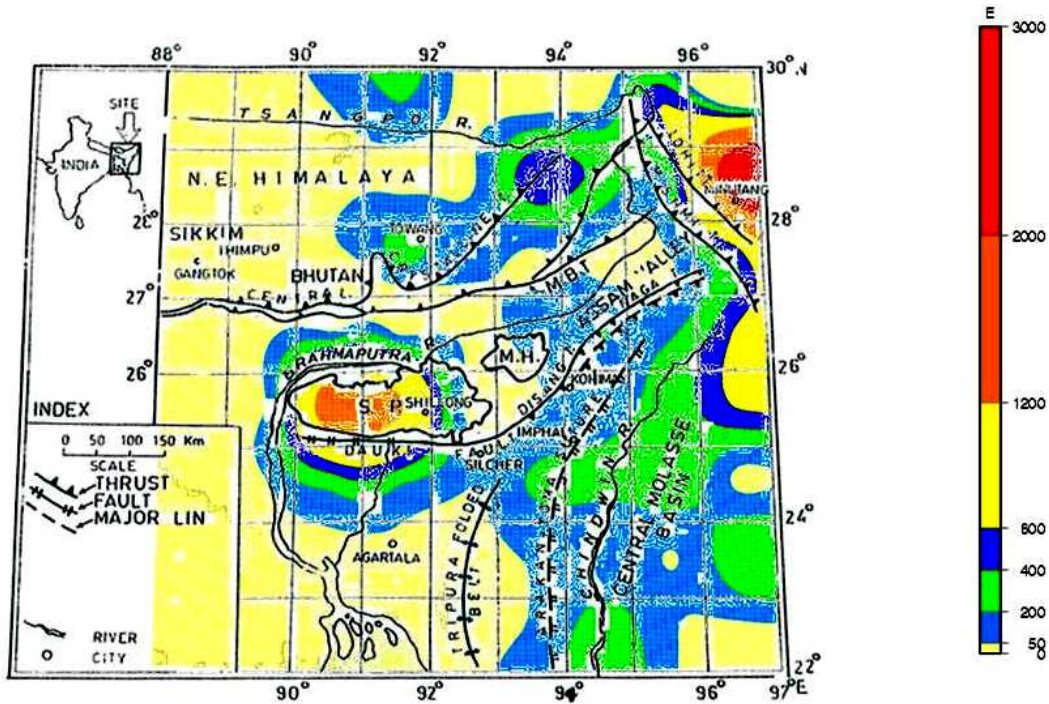


Fig. 3. Contours of the cumulative strain energy ( $E^{1/2}$ ) released during the period 1897-2000

(vi) The Bengal Basin ( $22^{\circ} - 25^{\circ} \text{N}$ ,  $90^{\circ} - 93^{\circ} \text{E}$ ) shows a moderate seismicity.

4. The relation between the seismic energy released, the surface and body wave magnitude is given by the following empirical formula: (Bath, 1979).

$$\text{Log } E = 4.78 + 2.57 \text{ Mb}$$

$$\text{Log } E = 12.24 + 1.44 \text{ Ms}$$

Where  $E$  is the energy in ergs,  $\text{Mb}$  &  $\text{Ms}$  are body wave and surface wave magnitudes respectively. The cumulative strain energy  $E^{1/2}$  has been calculated for  $1^{\circ} \times 1^{\circ}$  grids for the period 1897-2000 and the contours have been drawn (Fig. 3). It is noticed from the contour map that maximum energy is released in the area to the northeast of Lohit Thrust, second highest in the Shillong Plateau and third highest energy is released in the area to the northwest of Crystalline Thrust.

5. The frequency-magnitude relation (Gutenberg and Richter, 1944) is described using the empirical Gutenberg-Richter relationship as :

$$\text{Log } N = a - b^*M$$

Where  $N$  is cumulative number of events with magnitude  $\geq M$  in a given time period and  $a$  &  $b$  are constants. The  $b$ -value has often been used as a means to characterize the tectonic setting of a region. The  $b$ -value represents a statistical measurement of the relative abundance of large and small events in the group. A higher  $b$ -value means that a smaller fraction of the total events occurs at the higher magnitudes.

Here  $b$ -value has been calculated by using SEISAN Software with the Maximum Likelihood method as well as with the Least Squares for the different regions. The  $b$ -values have been calculated for magnitude  $\geq 4.0$  for the period 1963 - 2000 and for magnitude  $\geq 5.0$  for the periods of 1897 - 1962 and 1897 - 2000 for different tectonic regions. The  $b$ -values calculated from both the methods are comparable except the values for the magnitude  $\geq 4.0$  for the period 1963 - 2000, in this case  $b$ -values calculated with Least Squares method are considerably higher than the  $b$ -values calculated with the Maximum Likelihood method (Table 2). However,  $b$ -values for the whole studied region with the Maximum Likelihood method and the Least Squares fit yield a  $b$ -value of 1.02 and 1.05 respectively, which is very close to the global average of unity and are also comparable with the earlier study results (Chaudhary and Srivastava, 1976).

**TABLE 2**  
**a and b values for different regions of northeast India & northern Burma**

Tectonic regions	Parameters	Data Set 1897 – 2000 M ≥ 5.0		Data Set 1897 – 1962 M ≥ 5.0		Data Set 1963 – 2000 M ≥ 4.0	
		M.L.	L.S.	M.L.	L.S.	M.L.	L.S.
		1. Eastern Himalaya and Crystalline Thrust	a	5.62	6.35	4.08	5.87
	b	0.71	0.84	0.48	0.77	0.63	1.11
2. Lohit Thrust, Mishmi Thrust, Naga Thrust and Assam Valley	a	4.30	5.94	3.77	5.86	4.62	7.45
	b	0.49	0.74	0.41	0.73	0.67	1.26
3. Shillong Plateau and Tripura Folded Belt	a	5.46	4.39	4.14	4.04	4.71	6.21
	b	0.69	0.54	0.50	0.50	0.66	0.97
4. Mikir Hills, Disang Thrust, Arakan Yoma Suture Zone and Central Molasse Basin	a	6.07	6.44	4.26	5.79	5.37	7.66
	b	0.74	0.81	0.46	0.72	0.70	1.14

6. All the tectonic units of NE India and Burma including the Eastern Himalaya in the north, the Mishmi/Lohit Thrusts region in the east, the Shillong Plateau, the Mikir Hills and the adjacent area of Assam Valley, the Arakan-Yoma Folded Belt of Burma are seismically active. The seismicity is attributable to the release of strains, which are continuously accumulating as a result of collision of the Indian plate with the Eurasian plate. The seismic data is presented in the form of epicentral maps for magnitude  $\geq 5.0$  &  $4.0 - 4.9$ . It is observed that the area of highest seismicity lies along the Arakan-Yoma ranges and Molasse Basin of Burma, where active plate subduction processes are taking place. It is also noticed from the contour map of strain energy released that maximum energy is released in the area to the northeast of Lohit Thrust, second highest in the Shillong Plateau and third highest energy is released in the area to the northwest of Crystalline Thrust.

Over the Indian peninsula the zone of highest seismicity lies in the Himalaya and the area to the northwest of Mikir Hills. Other areas, which are very active, include the Shillong Plateau and the Mishmi Thrust region. The upper Assam Valley and the Bengal Basin are relatively inactive. The study of seismicity and its relationship to tectonics throws an interesting light on the nature of processes of plate collision taking place in the region.

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