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Earthquake Distribution in Northeast India from 1961-2010

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Abstract: ***This study investigated earthquake distribution in Northeast India from 1961 to 2010 with body wave magnitude, $M_b \geq 2.9$. Measure of central tendencies and spread, bar chart, pie chart, scatter plot were the statistical tools used. The data were obtained from International Seismological Centre (ISC) On-line Bulletin, United Kingdom from 1st January 1961 to 31st December, 2010 (50years). Frequency-Magnitude Relationship was employed and the constants were calculated to be a=6.80 and b=0.93. The findings of the study revealed that Northeast India is characterized majorly by minor and light earthquakes with low spatial spread. The rate of seismic activity for magnitude range 2.0-2.9, 3.0-3.9 is regular while for 4.0-4.9, 5.0-5.9 and 6.0-6.9 are irregular or fluctuating. It therefore implies that these trends may continue in future, but the probability of occurrence of great earthquake is low. However, one has to take caution because tectonic activities of deformation and uncertainties of occurrence of earthquake are not well understood. Hence, the possibility of occurrence of large earthquakes as a result of uncertainties associated with earthquake predictions, especially in intraplate and plate-boundary regions.***

Keywords: Frequency-Magnitude relationship, seismicity, seismotectonic, epicentre, intraplate region, plate-boundary region.

1. Introduction

The occurrence of earthquake around the world has attracted the attention of many seismologists and researchers. This global disaster is always in the headlines of the social media. Earthquakes occur as a result of movements along the faults that have evolved through geological and tectonic processes. These are most disastrous of all the natural disasters as they affect large areas causing death, injuries, floods, fires and destruction of physical resources on a massive scale [5]. These occur without any early warning and are therefore unpredictable. The extent to which an earthquake can cause damage depends on its magnitude, location and time. The deaths recorded during an earthquake mostly occur as a result of collapse of the buildings.

Northeast India has the highest level of seismic hazard potential [6]. The region has experienced two great earthquakes, Shillong Earthquake of 1897 and Assam Earthquake of 1950. According to the Global Seismic Hazard Assessment Programme (GSHAP), this region is of high risk with peak acceleration increasing in the range 0.35-0.40g [7]. The rapid population density and urbanization in the northeast India has resulted in the construction of storey structures different from Assam-type buildings at the time of occurrence of great earthquakes, thereby increasing the vulnerability of these structures to earthquakes.

The seismologist's aim is to predict occurrence of earthquake by studying past and future events so as to reduce the effect of earthquake damage on both man and property.

In this paper, our objective is to provide useful information on the distribution and frequency of occurrence of earthquakes in Northeast India.

2. Materials and Method

2.1 Seismicity and seismotectonic of Northeast India

Northeast India is among the six most seismically active regions of the world, the other being Mexico, Taiwan, California, Japan and Turkey. It is situated at the junction of Himalayan arc to the north and Burmese arc to the east [5]. The region has experienced eighteen (18) large earthquakes $(M \geq 7)$ during the last hundred years which includes the great earthquakes of Shillong (1897, $M = 8.7$) and Assam-Tibet border (1950, $M = 8.7$). Other small and micro earthquakes have also been experienced in this region is as a result of the collision tectonics between the Indian plate and the Eurasian plate in the north and seduction tectonics along the Indo-Myanmar range (IMR) in the east [2], [3] and [4].

Northeastern region is divided into five seismotectonic zones (Figure1). These include Zone-A Eastern-Himalayan collision, which is associated with a series of north heading thrusts. The most important thrusts are the Main Boundary Thrust (MBT), Main Central Thrust (MCT) and Main Frontal Thrust (MFT). Zone-B is also called the Syntaxis Zone which is the meeting place of Himalayan and Burmese Arc. The main fracture of this zone is Mishmi Thrust, Lohit Thrust and a part of Disang Thrust. Zone-C, the Indo-Burma range is characterized by Arakan Yoma, Chin Hills, Sagaing Fault and Schuppon Belt which is mainly situated by Naga and Disang Thrust. Zone-D is plate boundary zone of Shillong plateau and Assam valley is made up of Shillong Massif, Mikir Hills, Tista Fault, Dhubri Fault, Kopili Lineament, Dapsy Thrust, a part of Naga Thrust and a part of Brahmaputra Fault. The southern margin of the Shillong Massif is characterized by the Dauki Fault which has been interpreted to have strike slip displacement [9]. Zone-E consists of Bengal Basin and Tripura-Mizo Fold Belt. The main fractures of this zone are Padma Fault, Yamuna Fault, Kaladan Fault and Tapu Thrust.

Northeast India is associated with low seismicity and is due to intraplate activity while Tripura folded belt is characterized by moderate seismicity is as a result of plate-boundary activity. The Srimangal earthquake of 1918 (M=7.6) happened beneath the Bengal basin along the Sylhet fault. Cachar earthquake of 1984 happened in the Tripura fold belt likely as a result of movement along the Sylhet fault.

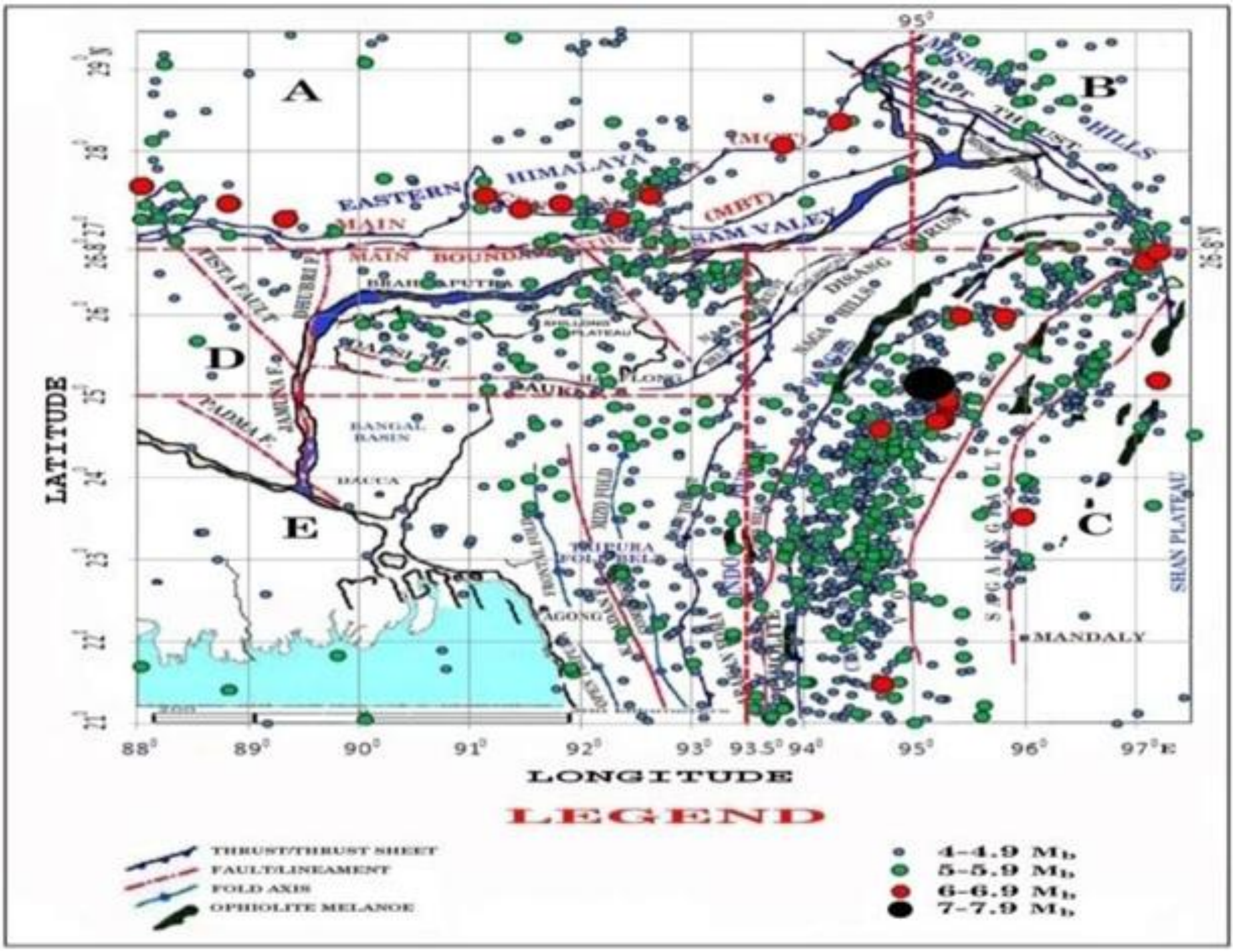

Figure 1: Map of the study area (After [8])

2.2 Method

The data set for this work were downloaded from the International Seismological Centre (ISC) On-line Bulletin, United Kingdom [10]. The selected data consisted of natural earthquakes with $M_b \geq 2.9$ for the study area from 1st January 1961 to 31st December 2010 (50years) with focal depth from 0-700km. The data set comprised date of occurrence of earthquake, origin time, coordinates of epicentre, magnitude, event identification, focal depth of earthquake and event type E. The region of study is situated within the coordinates 21.0^0-29.5^0N and 88.0^0E - 97.5^0E (Figure 1). A total of 2940 events were used in the study.

[11] developed a relationship for the frequency–magnitude distribution (FMD), in the form:

$$\mathrm{Log}N = a - bM \qquad (1)$$

For a given region and time interval, eqn(1) gives the cumulative number of earthquakes (N) with magnitude (M), where **a** and **b** are positive, real constants. The parameter **a** describes the seismic activity. It is determined by the event rate and for a given region depends on the volume and time window used. The **b** parameter is a tectonic parameter that describes the properties of the seismic medium.

3. Results

The results of the study are shown (Table 1 to Table 4) and Figure 2 to Figure 5.

Table 1: Distribution of events based on magnitude for each year

Year/Mag.	2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	Total
1961	0	0	0	0	0	0
1962	0	0	0	1	1	2
1963	0	0	0	1	0	1
1964	0	0	6	15	2	23
1965	0	0	3	10	0	13
1966	0	0	13	5	0	18
1967	0	0	17	7	0	24
1968	0	0	8	3	0	11
1969	0	0	9	7	1	17
1970	0	0	10	8	1	19
1971	0	0	7	9	0	16
1972	0	0	10	3	0	13
1973	0	0	14	3	0	17
1974	0	0	20	1	0	21
1975	0	0	17	8	0	25
1976	0	0	14	1	1	16
1977	0	0	11	5	0	16
1978	0	0	36	4	0	40
1979	0	1	35	6	0	42
1980	0	0	28	2	1	31
1981	0	1	34	3	0	38
1982	0	1	37	7	0	45
1983	0	0	25	13	0	38
1984	0	1	32	12	0	45
1985	0	2	31	5	0	38
1986	0	0	24	9	0	33
1987	0	1	35	6	0	42
1988	0	4	46	7	0	57
1989	0	4	41	10	0	55
1990	0	3	41	3	1	48
1991	0	6	49	9	1	65
1992	0	18	53	6	0	77
1993	0	22	54	2	0	78
1994	0	15	43	7	0	65
1995	0	11	60	2	1	74
1996	0	40	75	4	0	119
1997	0	38	57	5	0	100
1998	0	40	37	6	0	83
1999	0	25	48	4	0	77
2000	0	36	40	4	1	81
2001	0	42	49	4	0	95
2002	1	90	31	2	1	125
2003	0	90	53	2	0	145
2004	0	98	58	1	0	157
2005	0	58	39	7	0	104
2006	0	64	39	5	0	108
2007	0	98	41	2	0	141
2008	0	108	51	1	0	160
2009	0	98	39	7	1	145
2010	0	105	31	1	0	137
Total	**1**	**1120**	**1551**	**255**	**13**	**2940**

Table 2: Distribution of magnitude, frequency and cumulative frequency

M_b	Frequency N	Cumulative N
2.9	1	2940
3.0	2	2939
3.1	14	2937
3.2	21	2923
3.3	53	2902
3.4	103	2849
3.5	142	2746
3.6	161	2604
3.7	171	2443

3.8	222	2272
3.9	231	2050
4.0	217	1819
4.1	180	1602
4.2	176	1422
4.3	193	1246
4.4	150	1053
4.5	164	903
4.6	156	739
4.7	140	583
4.8	107	443
4.9	68	336
5.0	74	268
5.1	49	194
5.2	44	145
5.3	24	101
5.4	26	77
5.5	10	51
5.6	6	41
5.7	11	35
5.8	5	24
5.9	6	19
6.0	5	13
6.1	3	8
6.2	2	5
6.3	1	3
6.4	1	2
6.6	1	1

Table 3: Distribution of events based on frequency at an interval of 10-years

Year/Mag.	2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	Total
1961-1970	0	0	66	57	5	128
1971-1980	0	1	192	42	2	237
1981-1990	0	17	346	75	2	440
1991-2000	0	251	516	49	3	819
2001-2010	1	851	431	32	1	1316

From Table 3, the interval of 10 years was employed as follows: (1961-1970), (1971-1980), (1981-1990), (1991-2000) and (2001-2010). The frequency distribution of earthquakes that occurred within the time interval of 10 years in 2001-2010 was higher than previous 10 years interval. i.e. the frequency distribution increased from the time interval 1961-1970 to 2001-2010. This implies that the relative motion between the plates and plate-boundary is increasing with time and this gives rise to large accumulation of tectonic stress. The accumulated stress was the cause of increase of the number of events with time. The decrease in magnitude 6.0-6.9 from 3 during the fourth 10 years to 1 during the last 10 years indicates that a devastating earthquake is on the decrease in the study area (Table 3 and Figur2).

Table 4: Central tendency and spread

	Depth(m)	Magnitude
Mean	62.85	4.19
Median	52.65	4.1
Mode	33	3.9
Standard Deviation	41.45	0.55

The central tendency was carried out to get rough estimate of the average magnitude and the spread.

For these purposes mean, mode, median and standard deviation were calculated for magnitude and depth values (Table 4).

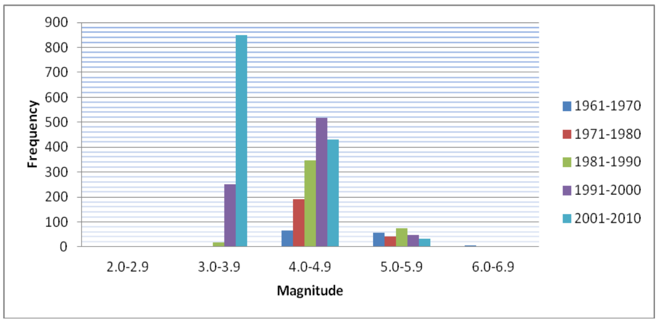

Figure 2: Comparison of frequency-Magnitude distribution over 10-year interval

Figure 2 showed that events of magnitude between 4.0 and 4.9 were most frequent, followed by magnitude 3.0-3.9 and the least frequent magnitude was 2.0-2.9 which was only one. It therefore means that Northeast India is majorly dominated by minor and light earthquakes.

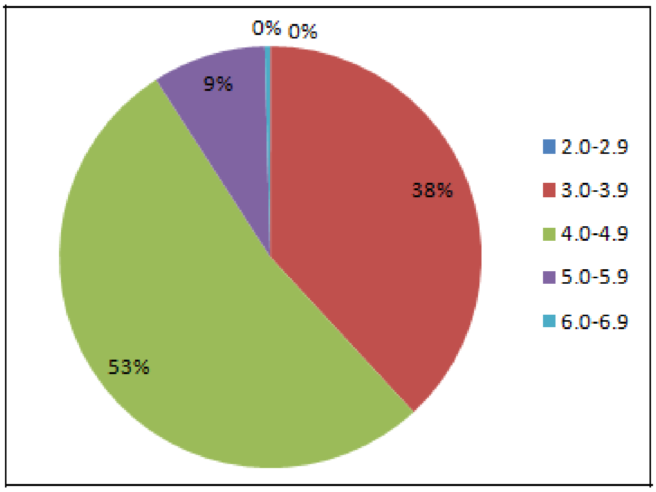

Figure 3: Pie chart showing the percentage of magnitude distribution for 50 year period (1961-2010)

The pie chart of the data was constructed and magnitude 4.0-4.9 was the most frequent (53%), followed by 3.0-3.9 (38%), 5.0-5.9 (9%), 6.0-6.9 (0.44%) and 2.0-2.9 (0.03%) was the least (Figure 3). This means that the earthquake distribution in Northeast India is majorly dominated by minor and light earthquakes.

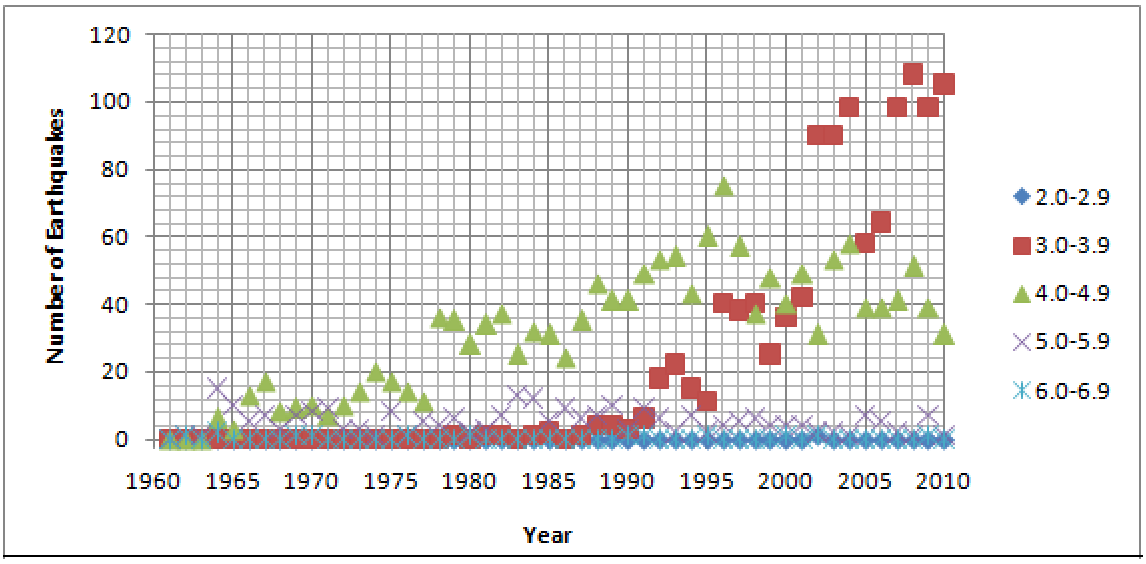

Figure 4: Distribution of number of earthquakes for each year from 1961-2010

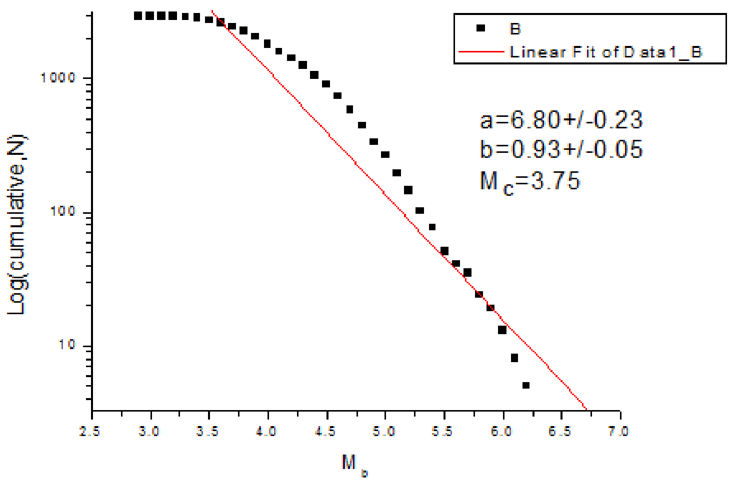

Figure 5: Frequency-magnitude relationship from 1961-2010.

4. Discussion

The bar chart in Figure 2 indicates that the mode is between magnitude 3.0 and 3.9. This is in consonance with the calculated measure of central tendency that has mode as 3.9 for the whole data set. Also, the mean magnitude of overall for the whole distribution is 4.19 while the median is 4.1 (Table 4). These indicate that majority of the seismic events in Northeast India are mostly minor and light types and few of moderate ones.

The intraplate and plate-boundary activities and the central tendency results affirmed that Northeast India is a region of minor and light earthquakes. But this region has witnessed eighteen (18) large earthquakes and minor and moderate ones in the last one hundred years because of the collision tectonics between the Indian plate and the Eurasian plate in the north and seduction tectonics along the Indo-Myanmar range (IMR) in the east [2], [3] and [4]. The percentage compositions of the overall data are 0.03%, 38%, 53.0%, 9% and 0.44% for the 2.0-2.9, 3.0-3.9, 4.0-4.9, 5.0-5.9 and 6.0-6.9 magnitude ranges respectively (Figure 3). The standard deviation value of 0.55 in relation to the calculated mean value shows that the data have no significant spread. This means that seismic events in this area Northeast India are not witnessing any significant spread due to the fact that earthquakes occurred in shallow epicentres and other minor low depth events [1].

The constants in the Frequency-Magnitude relationship were computed to **a**=6.80 and **b**= 0.93 (Figure 5). An intermediate ***b***-value probably means that the examined region is associated with moderate seismicity and low **a**-value is associated low seismicity. This also shows that Northeast India is predominantly minor and light seismicity a characteristic feature of intraplate regions. The rate of seismic activity for magnitude range 2.0-2.9, 3.0-3.9 is regular and for magnitude range 4.0-4.9, 5.0-5.9 and 6.0-6.9 is irregular or fluctuating (Table 3). It therefore means that these trends may continue in future, but the probability of occurrence of great earthquake is low. However, one has to take caution because tectonic activities of deformation and uncertainties of occurrence of earthquake are not well understood.

5. Conclusion

Northeast India is generally considered a region of low and moderate seismicity. It is concluded from this study of earthquake distribution for 50years that the study area is characterized majorly by minor and light earthquakes and a few of moderate earthquakes.

However, one has to take caution because tectonic activities of deformation and uncertainties of occurrence of earthquake are not well understood. Hence, there is possibility of occurrence of large earthquakes as a result of uncertainties associated with earthquake predictions, especially in intraplate and plate-boundary regions. Therefore civil engineers and builders should follow earthquake resistant code in the design and construction of structures.

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References

[1] Alabi, A.A., Akinyemi, O.D and Adewale, A. “Seiesmicity pattern in South Africa from 1986 to 2009”. Earth Science Research, 2(2), 1-10, 2013
[2] J.R. Kayal,. Earthquake source process in Northeast India: A review. Him. Geol., 17: 53-69, 1996
[3] J.R Kayal, “Seismicity of Northeast India and surroundings – development over the past 100 years”, Journal of Geophysics, 19(1): 9-34, 1998.
[4] S.K. Sarmah,. “The probability of occurrence of a high magnitude earthquake in Northeast India. Journal. of Geophysics”, 20(3): 129-135, (1999.
[5] R.P .Tiwari, “Status of seismicity in the Northeast India and earthquakes disaster mitigation”. ENVIS Bulletin: Himalayan Ecology, 10(1), 2016
[6] BIS (2002) IS 1893–2002 (Part 1): Indian standard criteria for earthquake resistant design of structures, part 1–general provisions and buildings. Bureau of Indian Standards, New Delhi
[7] S. C Bhatia, Ravi Kumar, M. and Gupta, H.K). “A probabilistic seismic hazard map of India and adjoining regions”. Ann di Geofis 42:1153–1166, 1999
[8] P. Talukdar. “Seismic study and spatial variation of b-vaue in Northeast India”, IOSR Journal of Applied Physics, 4(3), 31-40, 2013
[9] Evans, P., “Tectonic Framework of Assam”. Jour. Geol. Soc. India, 5, 80-96, 1964
[10] Data retrieved from ISC website: International Seismological Centre, On-line Bulletin, http:www.isc.ac.uk, Internatl. seis. cent., Thatcham, United Kingdom, 2013
[11] Gutenberg, B. and Richter, C. “Seismicity of the Earth and associated phenomena”. Princeton Univ. Press , Princeton , NY., 1954