

Why North-Eastern Region Falls Under High Seismic Zone

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ABSTRACT: The North-Eastern Region (NER) of India is the most varied but picturesque and beautiful area of rolling forested hills and lush green fields. It has remained a touchy region both politically and geologically. Encompassing a sensitive border zone where India meets Bhutan, Tibet/China, Myanmar and Bangla Desh, this picturesque region is having mountainous terrain all around with Assam Plains in the center. The NER is a land of social, cultural and ecological diversity. Endowed with rich natural resources, it has peculiar characteristic of environmental conditions and fragile ecosystem. Furthermore, the NER is under threat from seismic point of view, and thus, is restless. To understand the occurrence of earthquakes in NER, it is essential to know the tectonic set up of the region. The NER comprises nearly seven geo-tectonic terranes, viz., Eastern Himalaya, Mishmi Block, Naga Hills, Assam Valley, Shillong Plateau & Mikir Hills, Arakan- Yoma Folded Belt, and Bengal Basin. The Eastern Himalaya shows typical Himalayan tectonic belts, such as Siwalik, Gondwana, Miri-Buxa, Bomdila and Sela from south to north, each separated by a thrust. Mishmi Block, which in fact is part of the Shan-Thailand- Malayian Block, is seen in juxtaposition with the Himalayan Block along a Suture Zone. In Arunachal this block shows the Mishmi Massif comprises of granodiorite, diorite and granitic gneiss. Naga Hills shows suppean structure of Tertiary sediments and the ophiolitic mealange. Assam Valley lies between the Himalaya & Naga Hills in the eastern part and between the Himalaya & Shillong Plateau in the western part. The valley has been formed as a result of deposition of sediments brought by the rivers from rising Himalaya, Mishmi & Naga Hills, and Shillong Plateau &

Mikir Hills form a part of the main land. Mikir Hills are detached from the Shillong Plateau by NNW-SSE trending Kopili Lineament. Shillong Plateau is delimited by E-W trending Dauki Fault in the south, Yamuna Lineament in the west. There has been a history of continuous uplift of the Plateau since Cretaceous time and submergence of the area lying to the north & south. Arakan-Yoma Folded Belt consists of a series of thrusts and thrust slices that lies to the west of Central Burma molasse basin. Bengal Basin lies south of Shillong Plateau and is bounded by Tripura Folded Belt in the east and Indian Peninsula in the west, and was formed during Eocene to Pleistocene time. Arunachal Pradesh, representing the Himalaya, is trending SW-NE and then bends acutely near the Siang River in NW-SE direction. Along its southeastern corner, it turns again, trending NE-SW. This bend was earlier known as the 'Syntaxial Bend' geologically. However, it is not the 'Syntaxial Bend' in true sense. In fact, it is because of the geological set up of three mountain systems of different origin that occur in juxtaposition. These are : i) Himalayan ranges, ii) Mishmi hill ranges (NW part of Shan-Malaysia Plate), and iii) Naga- Patkai-Arakan ranges. These tectonic zones are geodynamically active. In fact, the Indian sub-continent is moving in northeastern direction @ approx 5.4 cm per year and pressing the Himalaya very hard. In the NER, the Meghalaya-Mikir block is pushing, and consequently, the land of Assam is sliding northwards under the Arunachal Himalaya and eastwards beneath the Indo-Myanmarese Ranges. It is evident from uplift of the Meghalaya Block, sudden narrowing of the Brahmaputra River near Guwahati, severe deformation and recurrent seismicity in the region. Thus, strain is building up, which is being released periodically, as such seismicity is very common in this region, which has been experiencing frequent earthquakes ranging from major to minor intensity. The seismic records show that this region has experienced two great earthquakes of Magnitude >8.7; 22 earthquakes of Magnitude >7; 32 earthquakes of Magnitude between 6 to 7; and innumerable number of smaller earthquakes till 2007. As a result, the entire NER falls under the high seismic zone, i.e. Zone V. The NER, thus, has remained restless and consequently the geo-environment is under threat. Owing to the active geodynamic condition of the terrane, even small tampering with the ecological- geological balance can initiate environmental changes. Thus, there is a need to take extraordinary care, especially in the developmental activities, to minimize the adverse impact on the geo-environment of the region.

I. INTRODUCTION

The North Eastern Region (NER) of India is the most varied but picturesque area of rolling forested hills and lush green fields. It has remained a touchy region both politically and geologically. Encompassing a sensitive border zone of India with Bhutan, Tibet/China, Myanmar and Bangla Desh, this scenic region is having mountainous terrain all around with Assam Plains in the center. The NER is a land of social, cultural and ecological diversity. Endowed with rich natural resources, it has peculiar characteristic of environmental conditions and fragile ecosystem. However, the NER is under threat of seismicity, and thus, the NER remains restless.

Seismicity is defined as the distribution of earthquake activity in time, location, magnitude and depth during the historical and recent instrumented period. Understanding the seismic hazard in a region can be enhanced by comparing earthquake mechanism data with geodetic observations of strain accumulation and geologic information on tectonics and neotectonics. Tectonics is the study of the origin and arrangement of the broad structural features of the earth's surface involving geological and geomorphological processes in the geological past. Neotectonics, on the other hand, implies these processes during the Quaternary Period and is still continuing in the present time. As such, a number of earthquakes are occurring in NER periodically on regular basis. To understand the occurrence of earthquakes, it is essential to know the tectonic set up of the region.

II. TECTONIC SET UP OF NE REGION

The NE Region comprises nearly seven geo-tectonic terranes, viz., North-Eastern Himalaya, Mishmi Block, Naga Hills, Assam Valley, Shillong Plateau & Mikir Hills, Arakan-Yoma Folded Belt, and Bengal Basin (**Figure 1**).

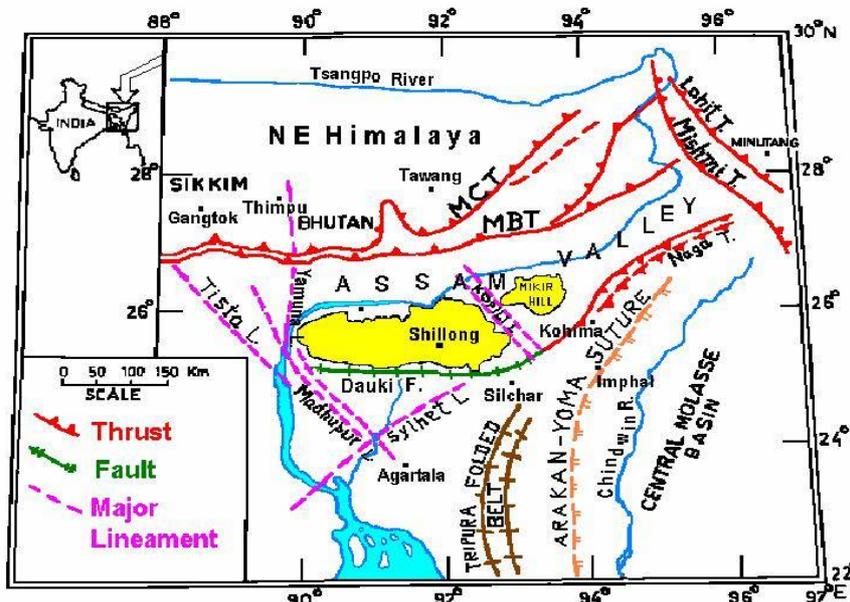


Figure 1. Map showing Tectonic Features in NE Region.

The North-Eastern Himalayan Terrane includes the Himalayan Ranges that are continuing from Darjeeling, Sikkim and Bhutan in the western part. These ranges continue up to the eastern part of Arunachal in Upper and East Siang districts and partly in Dibang Valley and Lohit districts.

Geologically, the **North-Eastern Himalayan Terrane** in Arunachal Pradesh is divisible into three geotectonic domains. These, in ascending order, are Outer Himalaya, Lesser Himalaya, and Higher Himalaya, each separated by a boundary thrust, viz., Himalayan Frontal Fault (HFF), Main Boundary Thrust (MBT), and Main Central Thrust (MCT). These domains exhibit distinctive litho-tectonic units, which are bounded by thrusts (Table 1). These litho-tectonic units, from south to north, are Siwalik, Gondwana, Miri-Buxa, Bomdila and Sela.

Table 1. Litho-Tectonic Units in the NE Himalaya

Geotectonic Zone	Litho-tectonic Unit	Lithology
Mishmi Block	Lohit Plutonic Complex	Diorite, granodiorite, hornblende granite, leucogranite, aplite, tourmaline bearing pegmatites, biotite rich garnetiferous gneiss, banded gneiss, schists and marble bands
	----- Lohit Thrust -----	
Tidding Suture Zone	Tidding Formation	Meta volcanics, chlorite schist, serpentinised peridotites, foliated quartzite, grey marble with epidote and intrusive leucogranite
	----- Tidding Thrust (Tuting-Tidding Suture Zone) -----	
Higher Himalaya	Se La Group	Kyanite-sillimanite-staurolite schist and gneiss, marble, migmatite, garnet-mica schist, quartzite, ortho-augen gneiss and amphibolite. High-grade metamorphites at places intruded by young tourmaline granite
	----- Main Central Thrust (MCT) -----	
Lesser Himalaya	Bomdila Group	Low-grade argillaceous and arenaceous metamorphites, pene-contemporaneous basic volcanic and large-scale granitic intrusive
	Miri-Buxa Group	Dolomitic limestone, greenish phyllite and quartzite, pink and white ortho-quartzite, micaceous feldspathic sandstone, grit and conglomerate beds
	Gondwana Group	Polymictic tillite, shale with thin bands of siltstone and mudstone, alternate beds of feldspathic sandstone and carbonaceous slaty shale with thin beds of coal in between
----- Main Boundary Thrust (MBT) -----		
Outer Himalaya	Siwalik Group	Micaceous salt and pepper appearance sandstone, with minor siltstone, shale and conglomerate. Carbonised and silicified wood, lignite and coal lenses commonly embedded in the sandstone
	----- Himalayan Frontal Fault (HFF) -----	
Brahmaputra Alluvium		

Mishmi Block forms a part of the Shan-Thailand-Malaysian Plate that abuts against the Himalayan Terrane along a Suture Zone, viz., the Tuting-Tidding Suture Zone. In Arunachal, this block is present in Dibang Valley and Lohit districts.

The Mishmi Massif is comprised of diorite-granodiorite crystalline complex and the south-western boundary of this is marked by high angle NW-SE trending Mishmi Thrust (**Table 2**) along which this block is thrust on the adjoining rocks.

In this region, the NW-SE trending metamorphic belt is in direct contact with the Brahmaputra alluvium, along the Mishmi Thrust.

Table 2. Litho-Tectonic Units in the Mishmi Block (Lohit and Dibang valleys of Arunachal Pradesh)

Geotectonic Zone		Litho-tectonic Unit	Lithology
Mishmi Block		Lohit Plutonic Complex	Diorite, granodiorite, hornblende granite, leucogranite, aplite, tourmaline bearing pegmatites, biotite rich garnetiferous gneiss, banded gneiss, schists and marble bands
			----- Lohit Thrust -----
		Tidding Formation	Meta volcanics, chlorite schist, serpentinised peridotites, foliated quartzite, grey marble with epidote and intrusive leucogranite
----- Tidding Thrust (Tuting-Tidding Suture Zone) -----			
NE Himalaya	Higher Himalaya	Mayodiya Group	Kyanite-sillimanite bearing garnet-biotite schist and gneiss, psammitic gneiss, streaky gneiss, foliated quartzite and amphibolites
			----- Main Central Thrust -----
	Lesser Himalaya	Lalpani Group	Garnet-biotite schist and gneiss, banded gneiss, carbonaceous schist, foliated micaceous quartzite, marble and amphibolites
		Sewak Group	Sericite-chlorite puckered phyllonite, foliated sericitic quartzite, quartz porphyry, mylonitic augen gneiss and crystalline limestone
		Brahmaputra Alluvium	

Naga Hills shows Schuppen structure of Tertiary sediments and ophiolitic mealange. Litho-tectonic units have been given in **Table 3**.

Table 3. Litho-tectonic units of Naga Hills

Group	Formation	Lithology
Dihing Group	Dihing Formation	Bluish grey sandstone with a few sandy clay lenses in lower part, which gradually become pebbly in the upper part
	Namsang Formation	Bluish green to grey sandstone and green coloured clay. Sandstone contains lignite and silicified wood fragments
----- Naga Thrust -----		
Tipam Group	Girujan Formation	Mottled clay, ferruginous sandstone and lensoid bodies of conglomerates
	Tipam Formation	Bluish grey and green sandstone with a few siltstone and conglomeritic beds
Barail Group	Tikak Parbat Formation	White and grey sandy clay, shale and fine- to medium- brownish sandstone with coal seams at various levels
	Baragolai Formation	Cyclic sequence of sandstone, shale, siltstone, silty clay, carbonaceous shale and coal seams
Disang Group	Naogaon Formation	Grey, flaggy thin bedded sandstone with intercalation of dark grey splintery shale and sandy

	shale
Disang Formation	Thick sequence of splinter shale interbedded with thin beds of sandstone and siltstone
----- Disang Thrust -----	

Assam Valley lies between the Himalaya & Naga Hills in the eastern part, and between the Himalaya & Shillong Plateau in the western part. The valley has been formed as a result of deposition of sediments brought by the rivers from rising Himalaya, Mishmi & Naga Hills, and Shillong Plateau. The Assam Valley, also referred to as Brahmaputra Basin, exhibits fluvial sediments of the Quaternary Period.

The Brahmaputra basin is underlain by the basement rocks, which in turn, are covered by nearly horizontal to gently dipping Cenozoic sediments.

Shillong Plateau & Mikir Hills form a part of the main land. Mikir Hills are detached from the Shillong Plateau by NNW-SSE trending Kopili Lineament. Shillong Plateau is delimited by E-W trending Dauki Fault in the south, Yamuna Lineament in the west. There has been a history of continuous uplift of the Plateau since Cretaceous time and submergence of the area lying to the north & south.

Arakan-Yoma Folded Belt consists of a series of thrusts and thrust slices that lies to the west of Central Burma molasse basin.

Bengal Basin lies south of Shillong Plateau and is bounded by Tripura Folded Belt in the east and Indian Peninsula in the west, and was formed during Eocene to Pleistocene time.

III. STRUCTURE

Arunachal Pradesh, representing the NE Himalaya, is trending SW-NE and then bends acutely near the Siang River in NW-SE direction. Along its southeastern corner, it turns again, trending NE-SW. This bend was earlier known as the 'Syntaxial Bend' geologically. However, it is not the 'Syntaxial Bend' in true sense. In fact, it is because of the geological set up of three mountain systems of different origin that occur in juxtaposition (**Figure 2**) (Valdiya, 1998). These are : i) Himalayan ranges, ii) Mishmi Hill ranges (NW part of Shan-Malaysian Plate), and iii) Naga Hill ranges (part of Naga-Patkai-Arakan ranges). These tectonic zones are geodynamically active.

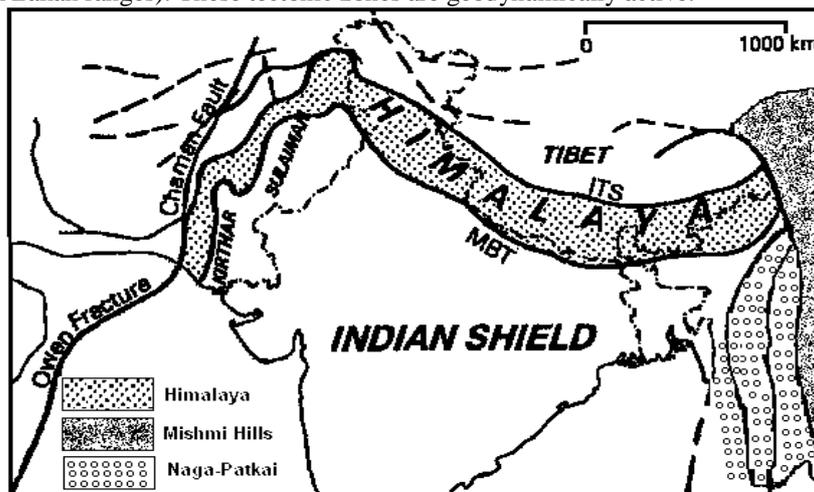


Figure 2. Juxtaposition of three different mountain systems in Eastern Arunachal Pradesh.

The major litho-stratigraphic units in Arunachal are thrust bound. Himalayan Frontal Fault (HFF), Main Boundary Thrust (MBT) and Main Central Thrust (MCT) are the boundary thrust planes.

The MCT is a regional tectonic feature that traverses not only the Arunachal Block, but whole length of the Himalaya. The MCT is a north dipping thrust and marks the tectonic boundary between the high-grade metamorphites of the Se

La Group and low to medium-grade metasediments of the Bomdila Group. In the eastern part, it abuts against the Tidding Suture in the Siang Valley.

The MBT is another regional tectonic feature of the Himalaya, which demarcates the tectonic boundary between the Lesser and Outer Himalayan Belts. It is also a north dipping thrust with ENE-WSW trend from the border with Bhutan in the west to Sessri River in the east. Further eastward, the MBT is concealed under the alluvium or truncated by the Mishmi Thrust.

The HFF marks the southern fringe of the Siwalik belt, bordering the Brahmaputra basin.

Bame Fault is another major tectonic plane in trending nearly N-S in Siang (Arunachal), which has truncated all the litho-tectonic units of the Lesser and Higher Himalaya.

The Mishmi Hill is characterized by a thick sequence of metasediments and associated granitic and mafic rocks, which have a regional NW-SE trend. These rocks abut against the Himalaya along the Tidding Suture in the SE, and Naga Hill ranges in the south along the Mishmi Thrust. The suture zone is composed predominantly of crystalline limestone, chlorite schist with serpentinite and ophiolites. Tidding Suture is a NW-SE trending tectonic feature that marks the plate boundary between the Indian and Central Burmese Plates. Other tectonic features include Lohit Thrust and Mishmi Thrust.

The Naga-Patkoi Ranges are subdivided into two zones/belts, viz., the Schuppen Belt and Patkoi Synclinorium. The rocks of the Disang, Barail and the Nahorkatia groups have been folded into a number of north-easterly plunging folds. In Naga Hills, Disang Thrust and Naga Thrust are the major tectonic features.

This Assam Valley is characterized by several sets of neotectonic faults of which the NW-SE and the E-W trending sets are most conspicuous. Significantly, the Brahmaputra river course is considered to be controlled at many places by E-W and NE trending fault systems. Significant structures here include Kopili Lineament, Dauki Fault, Sylhat Lineament, Tista Lineament, etc., which are the source of seismicity.

IV. SEISMICITY

The Indian sub-continent is moving in north-eastern direction approx @ 5.4 ± 4 cm per year persistently and pushing the Himalaya. In the NER, compressive movement of continental collision led to northward movement of the Arunachal Block and Meghalaya-Mikir Block. Consequently, the land of Assam is sliding northwards under the Arunachal Himalaya, and eastwards beneath the Indo-Myanmar Ranges (Valdiya, 1998). The Naga-Patkai-Arakan Ranges links up the so-called syntaxis with Andaman-Nicobar Island Arc, where Indian Ocean Floor is descending under the Malaysian Plate. It is evident from uplift of the Meghalaya Block, sudden narrowing of the Brahmaputra River near Guwahati, severe deformation, and recurrent seismicity in the region. Thus, strain is building up, which is being released periodically. As such seismicity is very common in this region, which has been experiencing frequent earthquakes ranging from major to minor intensity. The seismic records show that this region has experienced two great earthquakes of Magnitude >8.7 ; 22 earthquakes of Magnitude >7 ; 32 earthquakes of Magnitude between 6 to 7; and innumerable number of smaller earthquakes till 2007. Amongst these, Shillong Plateau Earthquake of June 12, 1897 (M=8.7), Dhubri Earthquake of July 3, 1930 (M=7.1), and Arunachal Pradesh-China Border Earthquake of August 15, 1950 (M=8.5) are the prominent earthquakes of this region.

The data for a period of five months per year (1980-86) further shows a total of 7,000 earthquakes in various parts of the region (Kayal, 1996). In addition, University of Roorkee (now called as IIT-Roorkee) and Geological Survey of India (GSI) have operated Micro-earthquake (MEQ) observatories over the Shillong Plateau and Assam Valley for short time periods to monitor micro-earthquakes for the period 1979-1990. This seismic studies indicate that ArakanYoma / Tripura folded Belt region is most active, followed by Mishmi-Lohit Thrust region, Shillong Plateau, NE Himalaya and Bengal Basin (Verma *et al.*, 1993). High seismicity is also noticed all along the Brahmaputra that lies on the northern fringes of the Shillong Plateau. Micro-seismicity studies shows that western margin of the Shillong Plateau is relatively more active (Kayal, 1987), which has been corroborated by Mukhopadhyay (1990) who has shown that several lineaments trending NNW-SSE and NNE-SSW are active in the western part of the Shillong Plateau. In Arunachal Pradesh, seismicity is mostly aligned along the MBT, MCT, Lohit and Mishmi thrusts.

The data represents the seismic recording carried out from time to time in a limited network, and the actual figure may, therefore, be much higher. It is unfortunate that there had not been continuous recording/monitoring the earthquake events in the past, which have been otherwise recorded mainly on project mode basis. The local seismic stations network in the NE Region includes the seismic stations mainly operated by North Eastern Institute of Science &

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NATIONAL WORKSHOP ON DISASTER MANAGEMENT (August 29th & 30th, 2014)

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Dept. of Civil Engineering & Centre for Management Studies, North Eastern Regional Institute of Science & Technology, Nirjuli - 791109, Arunachal Pradesh, India

Technology (NEIST) at Jorhat, formerly known as Regional Research Laboratory (RRL); Indian Meteorological Department, Government of India (IMD); National Geophysical Research Institute (NGRI); and Manipur University (MU) to contribute towards generation of seismological database.

Database generated by the local seismic network for the period November 1997 to December 1999 (Sitaram, 2002) shows a total recorded number of 263, 1536, and 1481 earthquake events during the year 1997, 1998 and 1999, respectively. The magnitude of these events varied from 2.1 to 5.9 in 1997, 1.6 to 5.3 in 1998 and 1.6 to 5.4 in 1999; and the depth ranges between 7 - 114 km in 1997, 4 - 163 in 1998 and 6 - 201 km in 1999. These earthquake events are controlled by specific local structural situations, viz., plate tectonic – collision phenomenon along the Eastern Himalaya and Indo-Myanmar border; and tectonic forces along thrusts, faults and lineaments. According to Sitaram (2002) this comparatively low percentage is mainly due to inadequate monitoring coverage of the regional seismicity with the local network.

The latest seismic data for the year 2003 shows 223 tremors of magnitude varying from 1.1 to 5.6 in the region, covering Assam, Arunachal, Shillong Plateau, Bengal Plains, and Indo-Myanmar region (RRL, 2004). Beside these, a single tremor of M 5.3 in Bhutan Himalaya has also been recorded.

V. CONCLUSIONS

The entire NER falls under the high seismic zone, i.e. Zone V, mainly because of the high number of earthquakes of varied magnitude frequently on regular basis. The NER, thus, has remained restless and consequently the geo-environment is under threat. Owing to the active geodynamic condition of the terrane, even small tampering with the ecological-geological balance can initiate environmental changes. Thus, there is a need to take extraordinary care, especially in the developmental activities, to minimize the adverse impact on the geo-environment of the region.

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