Seismic hazard potentiality of the frontal part of Mishmi Hills, Northeast India

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Abstract
Seismic hazard is the effect of an earthquake on the built environment and it is an important concept in engineering design and policy consideration. This study evaluates the seismic hazard of the Mishmi region. Seismic activities in this region are considered to be high due to the presence of trijunction of three mountain belts viz. the Himalayan belt, Mishmi Hills and Naga Hills. Numerous dams are coming up in the North East India and the largest hydroelectric power project of India is being planned in the Dibang Valley. Also, many parts of the region are being developed for industrial purposes. However, the North East India has a complex geology and several historical data references identify this region as tectonically active. Therefore, this study of hazard assessment is of utmost importance and would be helpful in assessing the seismic hazard for the entire frontal part of the Mishmi Hills.

The region has many active faults and experienced several earthquakes in the past, the biggest being the Great Assam Earthquake of 1950 whose epicenter lies close to the study area. To assess the tectonic activeness of the area, geomorphic indices (Mountain front sinuosity (S_{mf}), Steepness Index (S), Valley floor width to Valley height (V_f), Basin shape index (B_s), Stream Length-Gradient Index (SL), Asymmetry Factor (AF), Transverse Topographic Symmetry Factor (T)) were calculated and combined to yield Relative Tectonics Index (Iat) using Geographic Information System (GIS). The zonation map prepared in this study was compared with geological map of the study area and it was found that the identified hazardous zone consists of faults and thrusts. The lineaments assessment employed and field evidences proved neotectonics activities in the area. The seismo-tectonic map prepared in this work combined with morphometric analysis hints that the region can be hazardous in the future.

Keywords: Mishmi Hills; Active faults; Geomorphic Indices; Seismic Hazard.

Introduction

Seismic hazard assessment is important to minimize the loss of life and damage to infrastructure in seismically active regions. Historical records of earthquakes are pre-requisite for seismic hazard assessment and essential for probabilistic seismic hazard assessment technique.[22] Assessment of long term deformation history of fault is important[31] and hence characterization of seismsic hazard into small segments is effective.

There are several thrusts and faults present in the Mishmi Hills.[14] Due to this the Mishmi Hills is geologically unstable with high seismicity. From the seismological map of India, it is found that the area falls in Zone V and such places are likely to experience disastrous shallow-focus earthquakes.[32] The study area is a highly strained zone for potential earthquakes of large magnitude in the near future.[22]

Data obtained from the Northeast Institute of Science and Technology (NEIST), Jorhat, India, Indian Meteorological Department (IMD) and the U.S. Geological Survey (USGS) on the magnitude of the earthquakes in the region indicate the seismicity is concentrated in the active fault region. As drainage network examination in combination with morphometric analysis of topography is a useful tool to understand the tectonic activeness of a landscape[28], drainage basin analysis of the study area was evaluated along with relative rate of active tectonics. This kind of methodology has been found to be useful in various tectonically active areas such as SW, USA[27], the Southwestern Sierra Neveda of Spain[12] and Zagros, Iran.[11] In this study seven geographic indices were analyzed.

A phenomenal increase in the population density and infrastructural development in the Mishmi region were witnessed. Besides, unplanned urban areas have rapidly come up in the region in the past two decades. Many active faults in the region are discontinuing and dissected by transverse faults, which make the region seismically active. These factors increase the vulnerability of human population and civil infrastructure in the event of any earthquake of similar magnitude to that of the 1950. Therefore, it is necessary to assess the status of seismicity in the region realistically.

Keeping the above view, the objective of the study is to understand the regional seismic hazard of entire frontal part of Mishmi Hills. The potentiality of earthquakes on various active faults and its impact on the society is also discussed.

Study Area

Mishmi block lies in the northeastern corner of India bordering Myanmar and China tectonically separating the

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Eastern Himalayan and the Indo-Burmese (Myanmar) mobile belts, thus forming a linkage[25] (Fig. 1). Geologically and petrologically, the rock units can be broadly divided into several distinct belts (from south-west to north-east). All the lithotectonic units are trending in NW-SE direction and dipping towards NE. The belt comprises predominantly of hornblende bearing granodiorite and diorite, tonalite, biotite granite, hornblende gneiss and crystalline marble bands.[21]

This group of rocks has been termed as the Lohit Group. The central belt comprises metavolcanics, tremolite, actinolite schist, marble and serpentinite probably derived from the basic volcanic and volcanogenic rocks termed as the Tidding Group.[21] The NE belt referred to as the diorite-granodiorite complex (Mishmi massif) comprises medium to coarse grained diorite gneiss, late tectonic hornblende granodiorite, coarse grained biotite granodiorite with hornblende schist, amphibolite, meta-dolerite, metanorite and minor xenoliths of high-grade para-metamorphic crystalline marble.[25] The three lithotectonic belts discussed above have been mapped about 250 km from Noa Dihing Valley to Dibang Valley.

Noa Dihing, Lohit and Dibang are notable rivers in the region and are considered as tectonically unstable regions. Frequent earthquake tremors of tectonic origin occur in this region. Some severe earthquakes can be traced back to around 1696, but earthquake record keeping facility was not available at that time. Scientific record keeping of earthquake was made available since the mid nineteenth century. The earthquake of 1950 is the most notable whose shock is classed above VIII in the Richter scale. Due to the presence of thrusts and faults in the Mishmi Hills, the region is geologically unstable with high seismicity.

The Mishmi Crystalline (massif) thrusted above the Brahmaputra Alluvium along the Mishmi Thrust, in the north of the Mishmi formation, the serpentinite bearing Tidding formation over thrusts the crystalline along the Tidding Thrust and is overthrust by rock of Lohit Plutonic complex along the Lohit Thrust.[21] The Mishmi Crystalline is divided into two groups of rock: the Sewak group consisting of green schist facies metamorphism and the Lalpani group predominantly consisting of garnet grade rock. The Lalpani Thrust and Hawa Thrust demarcate the abrupt change of grade of metamorphosim.

Between Lalpani Thrust and Hawa Thrust, a thrust namely Hakan Thrust is present within Lalpani Group of rocks (Fig. 2). The central crystalline made up of high grade metamorphism of Mayodia group is situated between Lalpani Thrust in the southwest and Tidding Thrust in the northeast direction of the Mishmi hills. The Tidding formation ophiolitic mélange sequence is overthrust by the rocks of the Lohit Plutonic complex along the Lohit Thrust.[21]

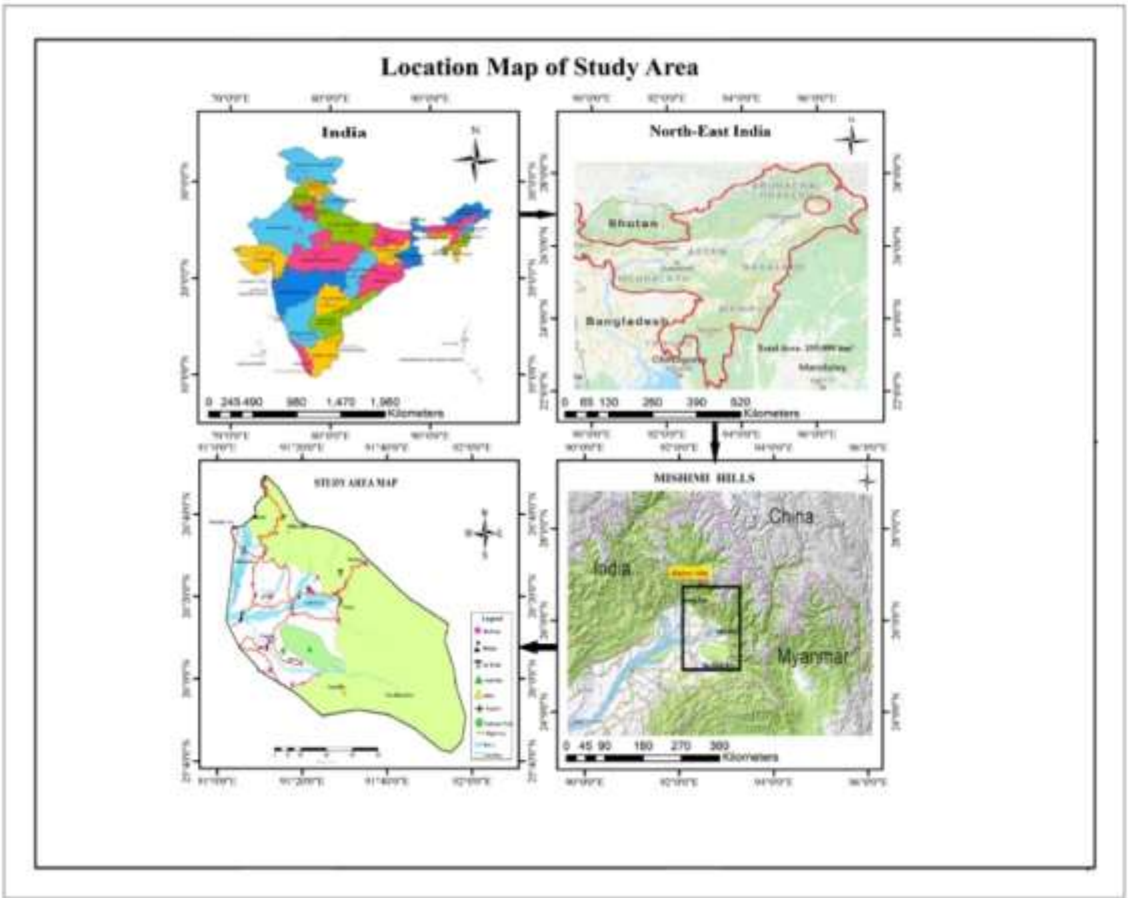

Fig. 1: Location map of the study area

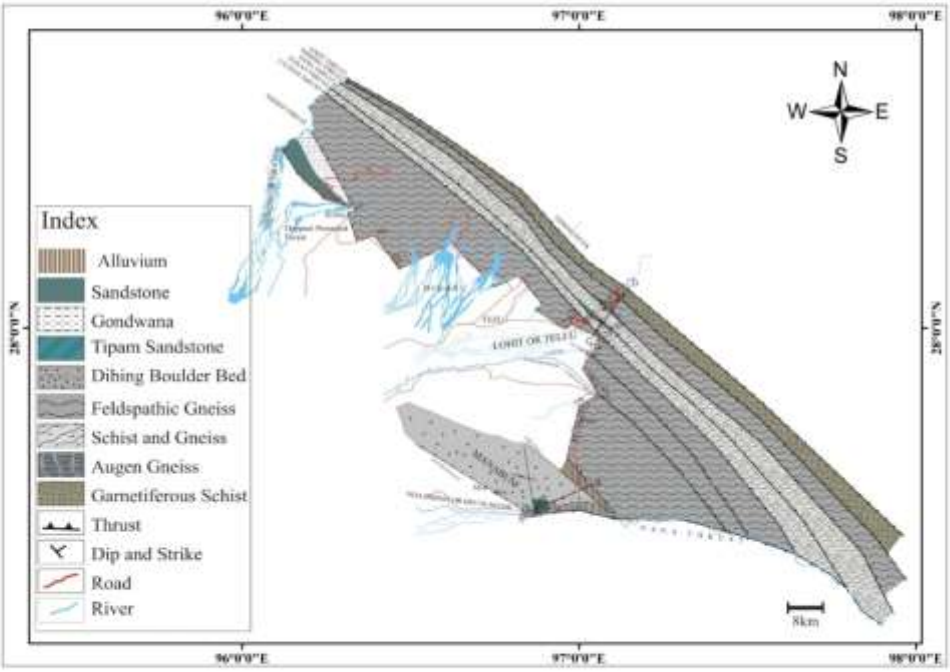

Fig. 2: Geological map of Mishmi Hills

Material and Methods

In this study 30m resolution Digital Elevation Model (DEM) extracted from ASTER data was superimposed on the topographic map from Survey of India using ArcGIS 10.4 and Global Mapper 18. The area studied comprises the three major rivers along with all its tributaries in the Mishmi Hills.

In assessing the spatial variability of the tectonic activity in the region, geomorphic indices and field investigation were carried out. Geomorphic indices useful for studying tectonics include Mountain front sinuosity (S_{mf}), Steepness Index (S), Valley floor width to Valley height (V_f), Basin shape index (B_s), Stream Length-Gradient Index (SL), Asymmetry Factor (AF) and Transverse Topographic Symmetry Factor (T).[3,4,15,31] These seven parameters were combined to determine the relative index of active tectonics (Iat) on the basis of which the study area was classified into several zones illustrating relative tectonic activity. These parameters usually respond to basin scale lithology changes and differential upliftment.[12]

Lineaments study was carried out with the help of SRTM satellite data used to generate DEM to facilitate the extraction of lineaments of the study. Topographic features that represent lineaments (such as straight valleys, continuous scraps, straight streams segments and rock boundaries) were analyzed in different azimuth angles in order to facilitate their extraction to the maximum possible extent. Further interpretation was done in Rose diagram in the Rozeta software.

Five field surveys were conducted to obtain the data that helped prepare the geological map for the study. The direction and dip values of the different beds were measured with the help of Brunton Compass. Global Positioning System (GPS) was used to get the location of the stations. Estimation of built-up damage probability due to earthquake in the study area was analyzed along with deterministic seismic hazard assessment approach.

The data on active faults and thrusts identified in the study area were combined with the seismicity map of the region and that formed the basis of the seismotectonic map prepared for the study. Earthquake zonation map was prepared using Arc GIS modeling technique. Historical earthquake data from 1950 onwards were collected from NEIST, IMD and USGS. The magnitude scales of the various institutions are not uniform, so the data used in this study were converted into M_W using established mathematical relations.[29]

Results and Discussion

Morphometry Analysis

Mountain front sinuosity (S_{mf}): The mountain front sinuosity index (S_{mf}) is defined as:[3,4]

$$S_{mf} = L_{mf} / L_s$$

where L_{mf} is the length of a mountain front along its base at the distinct break in slope and L_s is the straight line length of a whole mountain front. Generally, S_{mf} is less than 3 and approaches 1 where steep mountains rise along with a fault or fold.[4] It represents a balance between stream erosion processes tending to cut some parts of a mountain front and active tectonics that tends to produce straight mountain fronts.[3,16]

In this study, the S_{mf} was calculated for 4 mountain fronts using L_{mf} and L_s values measured from Shuttle Radar Topographic Mission (SRTM) images and divided into three classes viz. Class 1 ($1.0 \leq S_{mf} \geq 1.6$), Class 2 ($1.4 \leq S_{mf} \geq 3$) and Class 3 ($1.8 \leq S_{mf} \geq 5$).[17] The average S_{mf} value of the NW part of the Mishmi Block was found to be 2.24 which indicated a moderately active mountain front.

The S_{mf} of another section, Digaru River to Lohit River, was found to be 2.6 and moderately active. The S_{mf} of the NW-SE section of the Mishmi Hills, from Lohit River to Nao Dihing River, was found to be 2.44 and that of the Naga Hills section was found to be 2.72. Compiling all the above observation indicated that the whole area is moderately active.

Steepness index (S): Steepness index (S) is a tool that can be used to determine the tectonic activity of an area.

$S = H_p/D_p$

where H_p is the height of the peak of a mountain and D_p defines the distance between a mountain front and the peak of the mountain. Higher values of S indicate that an area is tectonically active whereas lower values indicate that an area is less active and erosion is more effective than the tectonic activity.[12]

In this study, the S was calculated for 22 basins located in the mountain front. The observed S for the study area ranged from 0.4 to 1.6. From the analysis of the mountain front basin sections of the study area using SRTM data, it was observed that the rivers are steep (Fig. 3) and the area can be considered as tectonically active.

Valley floor width to valley height (V_f): Another index sensitive to tectonic uplift is valley floor width to valley height (V_f) which may be expressed as:

$V_f = 2V_{fw}/ \{(E_{ld} - E_{sc}) + (E_{rd} - E_{sc})\}$

where V_{fw} is the width of a valley floor, E_{ld} is the elevation of the left valley divide, E_{rd} is the elevation of the right valley divide and E_{sc} is the elevation of the valley floor. High values of V_f are associated with low uplift rates where streams cut broad valley floors. Low values of V_f reflect deep valleys with streams that are actively incising, commonly associated with upliftment.[17] V_f measurements can be taken at a distance of about 250 m upstream from the mountain front[31] and approximately 1 km upstream from the mountain front.[3] For this study, 15 V_f measurements were taken at each of the stated distances (Table 1).

All the values were below 1.0 and SRTM data revealed that the valley is V-shaped. These two observations indicated that the mountain is highly active (Fig. 4).

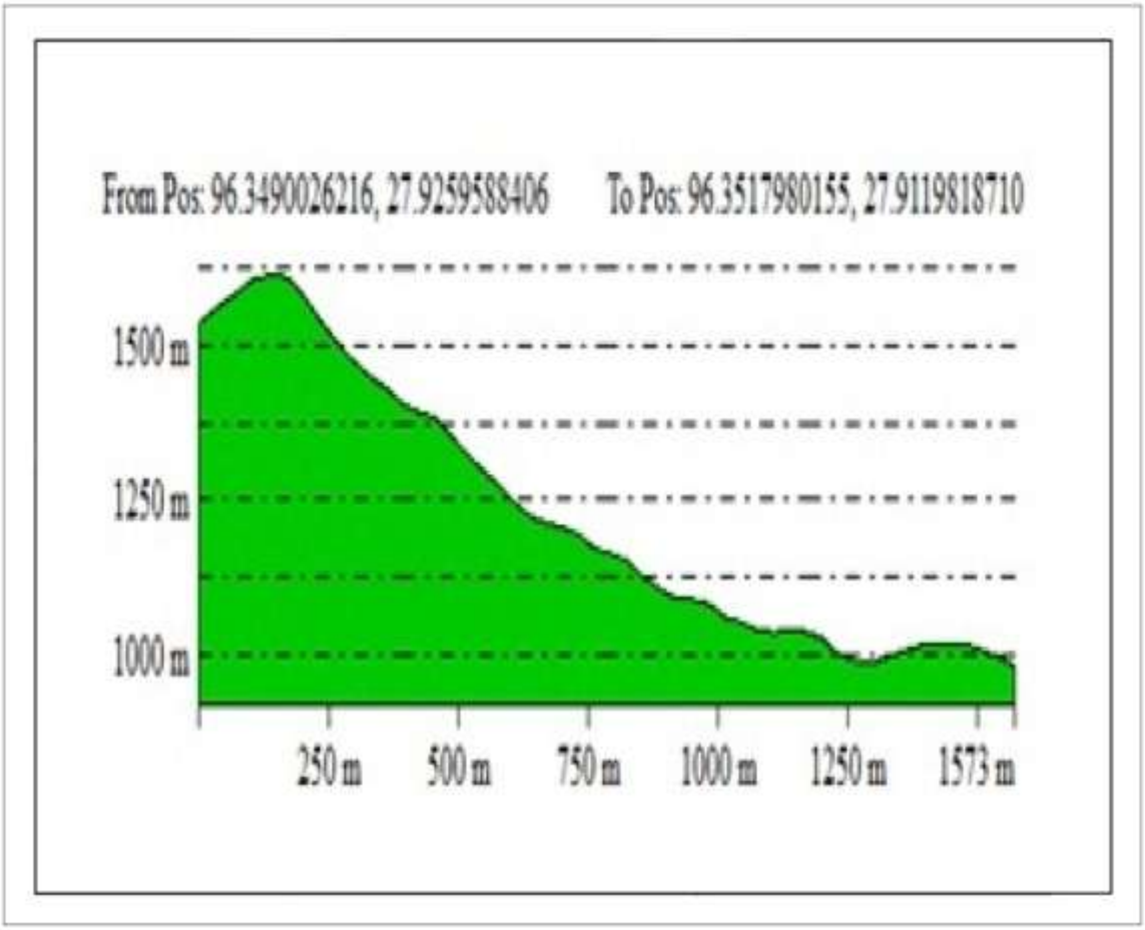

Fig. 3: Topographic profile of Steepness Index

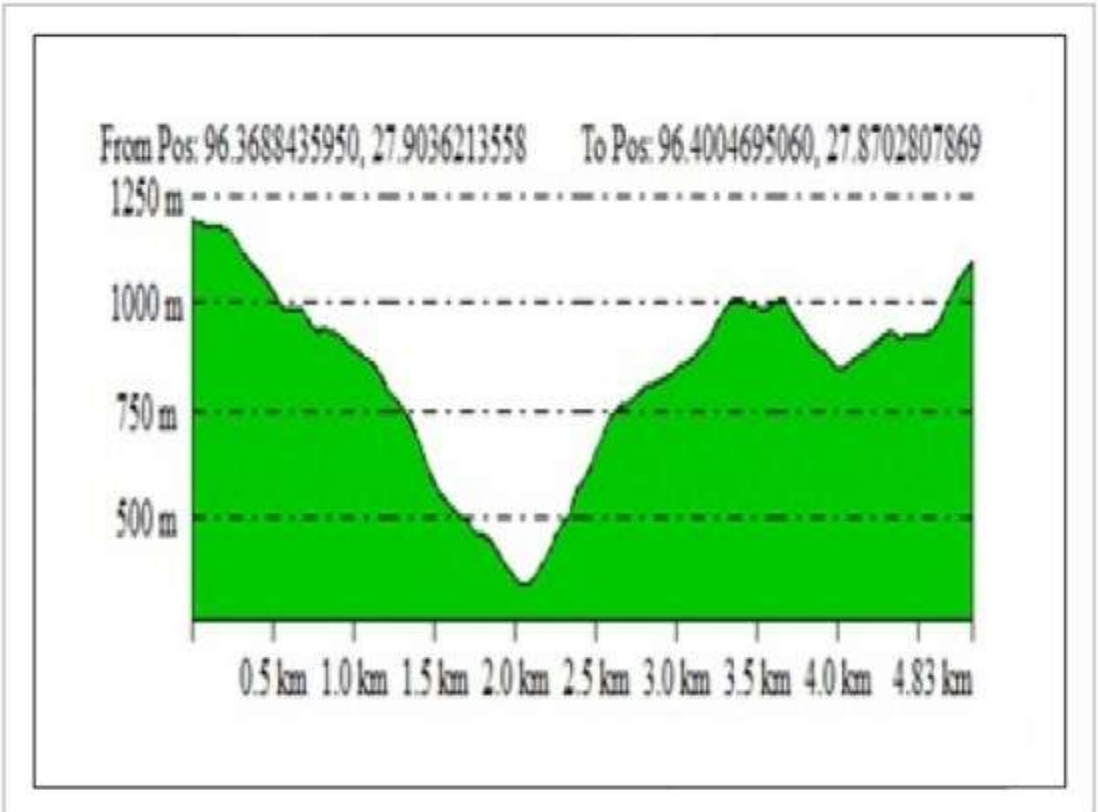

Fig. 4: Valley floor width to Valley height profile representation of V shape valley on Lai River

Basin shape index (Bs): The horizontal projection of a basin may be described by the basin shape index (B_s) or the elongation ratio.[26] Basin shape index is defined as:

$$B_s = B_l / B_w$$

where B_l is the length of a basin measured from the highest point and B_w is the width of a basin measured at its widest point. Relatively young drainage basins in tectonically active areas tend to be elongated in shape, normal to the topographic slope of a mountain.[3,26]

In this study, basin shape index of 289 basins were calculated and it was observed that the basins are elongated in shape which indicate active tectonics.

Stream length-gradient index (SL): Stream length-gradient index (SL) is calculated along a river and used to evaluate the erosional resistance of the rocks present along the river bank and the relative intensity of active tectonics.[1,18,33]

The SL is calculated using the following formula:

$$SL = (\Delta H / \Delta L).\ L$$

where L is the total channel length from the midpoint of a reach to the highest point on the channel and $\Delta H / \Delta L$ is the channel slope or gradient of the reach where ΔH represents the change in elevation for a particular channel of the reach with respect to ΔL that symbolizes the length of the reach.[1,15,18] SL can be used to evaluate relative tectonics activity.[18] Although high SL value for an area with soft rocks indicates recent tectonic activity, anomalously, low SL value may also represent such activity when rivers and streams flow through strike-slip fault (Fig. 5).

Calculations were done for 184 basins of the study area. The values were classified into 3 categories: 1 ($SL \geq 500$), 2 ($300 \leq SL \geq 500$) and 3 ($SL \leq 300$).[12] The result of the classification (Table 1) shows that there is an abrupt change of river profile along the Mishmi Thrust, Naga Thrust, Tiding Thrust and Lohit Thrust.

Asymmetry factor (AF): The asymmetry factor (AF) was developed to detect tectonic tilting at drainage basin scales or larger areas.[18] AF is defined as:

$$AF = 100\ (A_r / A_t)$$

where A_r is the area of a basin to the right (facing downstream) of a trunk stream and A_t is the total area of a drainage basin. For a stream network that forms and continues to flow in a stable setting, AF should be equal to 50. AF is sensitive to tilting perpendicular to the trend of the trunk stream. AF values greater or smaller than 50 suggest tilting of the catchment area of a basin.[12] AF values calculated for 289 basins in the study area were either greater than 50 or smaller than 50, which reveal basin asymmetry and active tectonics.

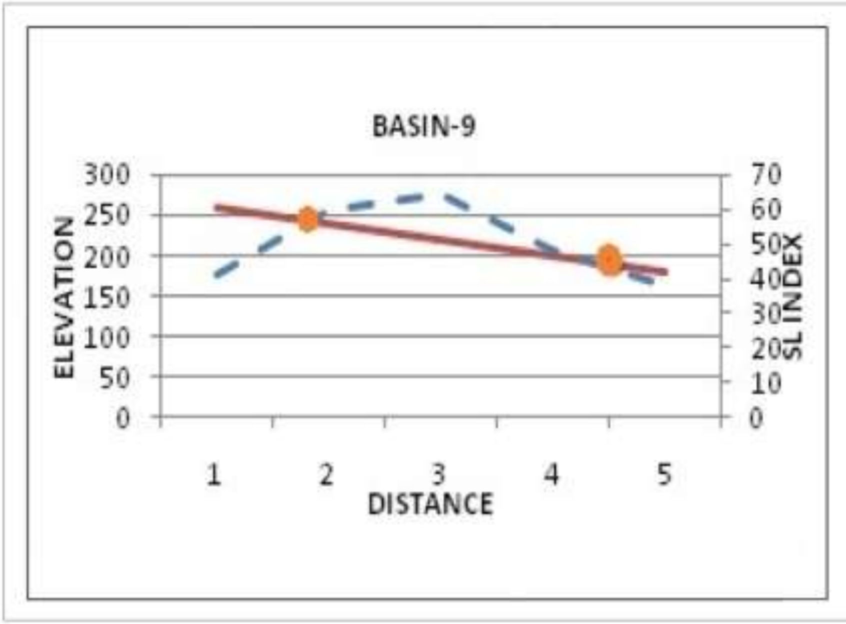

Fig. 5: Diagrams showing the relationship between the SL index and slope of the basins where the SL index changes abruptly

Transverse topographic symmetry factor (T): Transverse topographic symmetry factor (T) is defined as:

T = Da / Dd

where Da represents the distance from the midline of a drainage basin to the midline of the active meander belt and Dd corresponds to the distance from a basin midline to the basin divide.[12] T is a vector that has direction and magnitude that ranges from zero to one (T = 0 to 1), which reflects a perfect asymmetric basin or a tilted one.[2,8,9,18]

T values calculated for 289 basins in the study area fall within the range from 0.06 to 0.8. So it can be inferred that the basins are asymmetric due to tilting of the area. With the help of the values of T and the position of the of the trunk stream with respect to the midline of the basin, it was found that the trunk stream of the basins migrates towards the NW of the area between Dibang River and Digaru River; between Lohit River and Digaru River, the tilting is towards NW; in Naga Hills, the tilting of major rivers is towards SW. These observations reveal active tectonics in the area.

Seismotectonics Analysis

Lineament analysis: Lineaments are the terrain surface expression of fractures, joints and other geological phenomenon that occur anywhere from the terrain surface down to possibly great depth.[10] These are straight or gentle curve features on the earth surface which are topographically expressed as ridges, depressions, or aligned depressions. Tectonically active regions show higher intensities lineaments than tectonically quite zones.

The study area is covered with thick vegetation which hinders studying fractures, joints and other geological features in the field. This required employing software tools. The major lineaments were studied from the topo sheet with the help of the Software Global Mapper 18. The trend of lineaments was properly plotted in Rose diagram of Rozeta Software and the principal axis direction as well as the deformation direction was studied.

From the study, it is confirmed that the major lineaments of Mishmi Hills are aligned in the NW-SE direction (which is parallel to the thrusts present in the area) and the NE-SW direction (which is parallel to the cross fault) (Fig. 6). These observations reveal that tectonics plays an important role in the development of lineaments.

Spatial distribution of index value: Some rivers in the Mishmi Hills demonstrated higher values of SL compared to that of the Naga Hills (Fig. 5). Five hundred and ten numbers of SL values recorded in the subbasins in the Mishmi Hills along the Mishmi thrust were abnormally high. According to the acquired data, almost all anomalous values of SL are located in faults zone (Fig. 7). Also, the fault zone is seismically active with lateral strike-slip fault. Therefore, it can be said that the thrusts are still active.

Structural control plays a significant role in the development of basin asymmetry.[12] The recorded values of AF and T signify prominent asymmetry of the basins in the thrust zones. The distribution of V_f indicates that the rivers are deeply incised into the ground where they are above fault or thrust zones. The most elongated subbasins with the highest value of Bs occur along the thrust zones of the entire study area. S_{mf} values reflect the existence of a straight mountain front in the study area which is traversed by different cross faults. These observations reveal active tectonics in the study area.

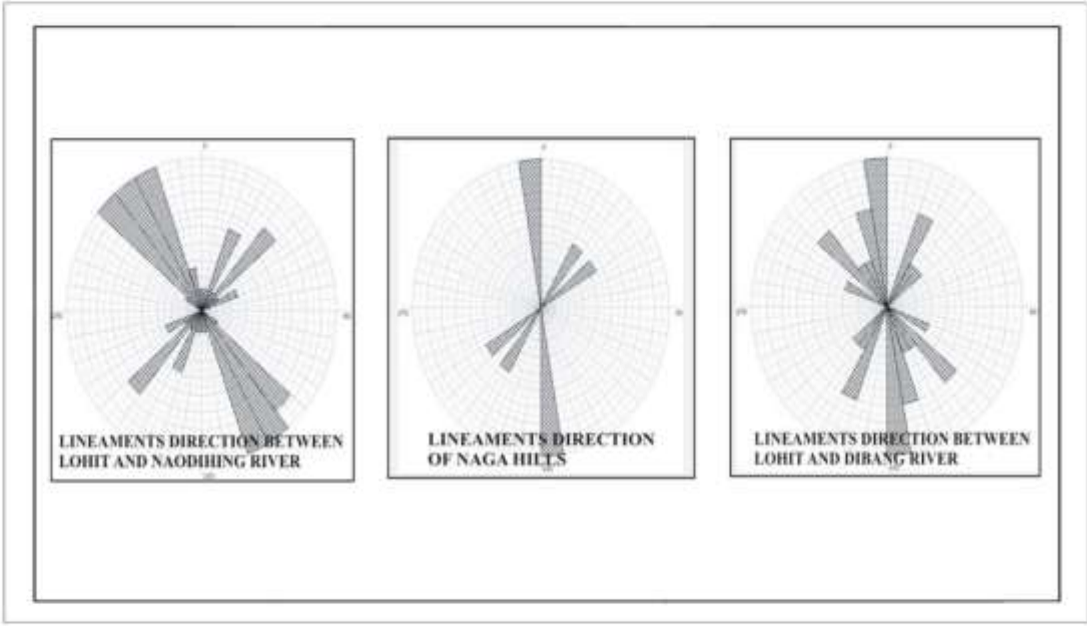

Fig. 6: Rozeta diagram showing the trends of lineation on Mishmi Hills

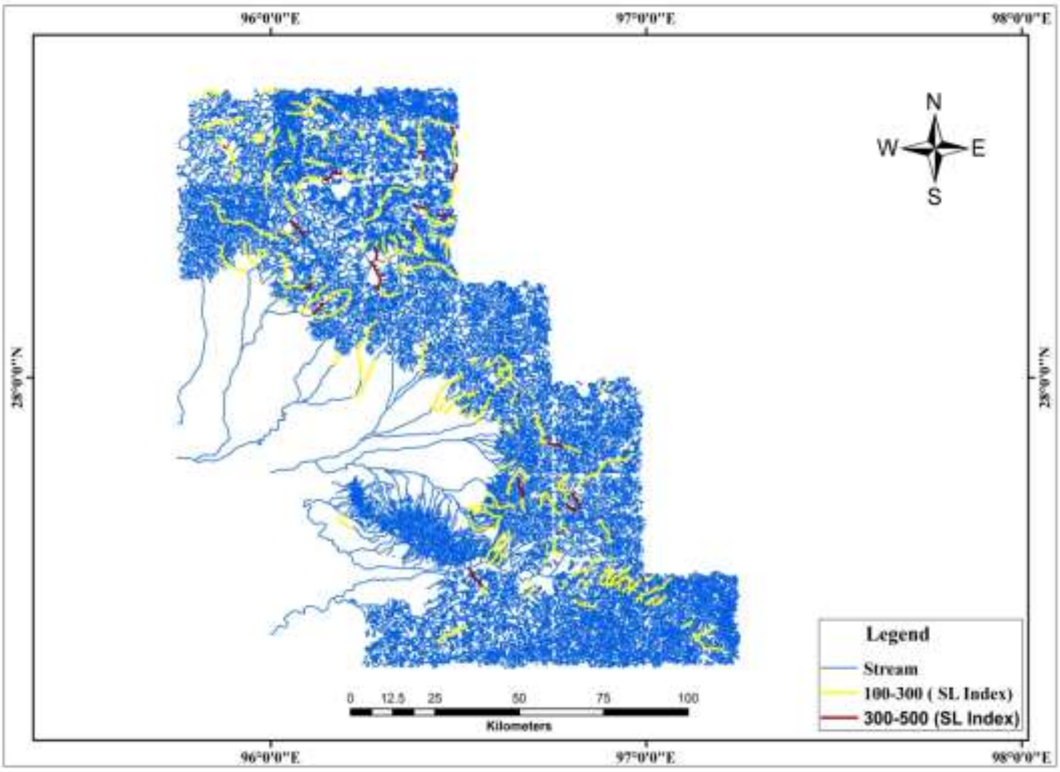

Fig. 7: Variation of SL index classes along the drainage network

Evaluation of Relative Tectonic activity (IAT): Previous studies on relative tectonic activity based on geomorphic indices tend to focus on a particular mountain front.[1,3,23,27] This study tried to evaluate tectonics in a wider area using a number of geomorphic parameters. The average of the five measured geomorphic indices (S_{mf}, V_f, SL, AF, Bs) was used to evaluate the distribution of relative tectonic activity in the study area.[12] The values of the index were divided into four classes to define the degree of active tectonics: Class 1-Very high ($1.0 \leq Iat < 1.5$); Class 2-High ($1.5 \leq Iat < 2.0$); Class 3-Moderate ($2.0 \leq Iat < 2.5$); and Class 4-Low ($2.5 \leq Iat$).[12]

The distribution of the four classes and the result of the classification for each basin are estimated. About 1% of the study area belongs to Class 1; 20% to Class 2; 67% to Class 3; and 12% to Class 4 (Fig. 8). IAT seemed high in the Dibang River, Lohit River and Nao Dihing River sub basins in the Mishmi Hills as well as in the basins in the Manabhom Anticline.

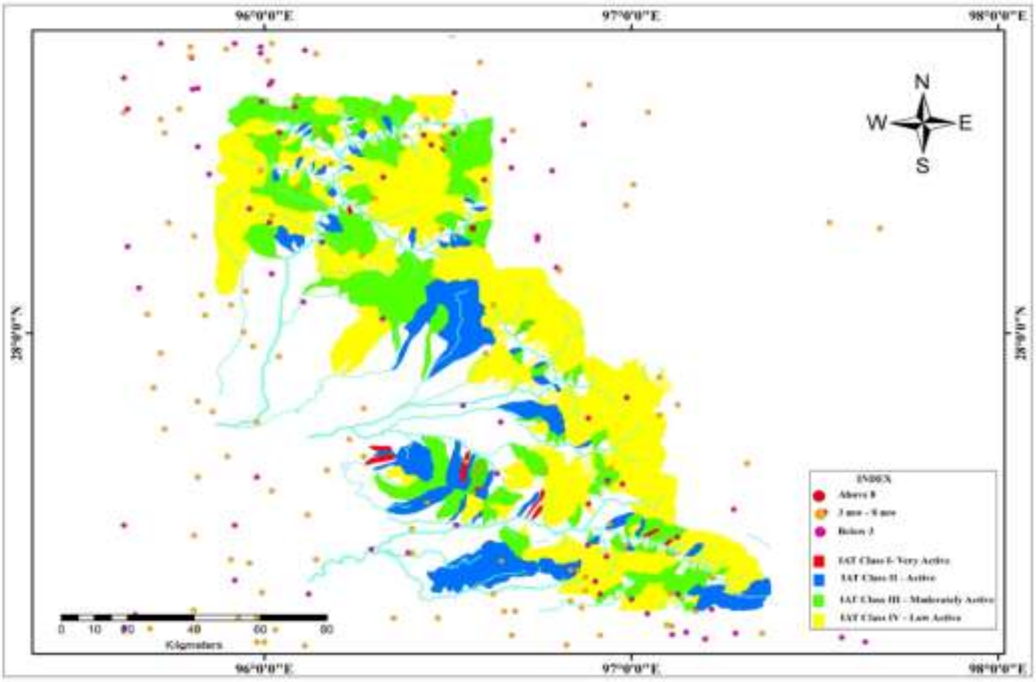

Fig. 8: Distribution of zones according to relative index of active tectonics (IAT) classes on Mishmi hills

The values of seven geomorphic indices show that there is strong tectonic control on drainage basin evolution in the study area. Based on spatial variation, the area was divided into four segments: Segment 1-Dibang River to Digaru River, Segment 2-Digaru River to Nao Dihing River, Segment 3-A part of the Naga Hills and Segment 4-Manabhom Anticline. The IAT of Segment 1 was found to be 2.30, Segment 2 measured 2.46, Segment 3 measured 2.42 and Segment 4 measured 2.17, indicating tectonically moderate activeness (Class 3 IAT) in each of the segments.

The IAT ranges of all morphotectonic parameters discussed above are based on previous studies in arid and semiarid climatic conditions. However, the study area is a subtropical region and it receives 2,000 to 5,000 mm of annual rainfall, giving the rivers here higher erosive power than the rivers in arid and semi arid regions. Hence, a revision of the ranges of the morphotectonic parameters indicating different class of tectonic activities for tropical and subtropical climate is required.

Geomorphic-Seismo-Field evidences: Shifting channels, incised alluvial fans, entrenched meanders and abrupt narrowing and widening of channels are strong indicators of tectonically active terrains.[5] The streams in the study area experience all of these activities. It has been noticed from IAT calculation that the Manabhom anticline is high tectonically active compared to Mishmi thrust because of the variation in rock composition.

The Mishmi thrust is composed of hard rocks whereas the Manabhom anticline is composed of soft rocks. The studied region suggests that the area along the major rivers is tectonically active with more activity near the thrust zones.

The seismicity marked the active nature of the thrusts present in the study area. Earthquake data from 1950 onwards indicate significant increase in the aftershocks following the 1950 earthquake, revealing the reactivation of the thrusts in the area. It has been noticed that the Cibi fault, Mishmi thrust, Kamlang thrust, Hakan thrust, Hawa thrust, Tiding thrust and Lohit thrust were experiencing epicenters from 1950 onwards. This suggests the area is tectonically active and a high earthquake potentiality in the thrust zones of the study area.

Some of the field evidences that depict tectonic activity along the Mishmi Thrust in recent times are triangular facets, alluvial fan and colluvial fan developed along the youthful scarps. Triangular facets are signature of youthful nature of the scarp in tectonically active terrains.[4,18] One of the direct evidences of active tectonics is deformation of quaternary sediments. Several events of folding in the Mishmi Hills during the late quaternary are noticed. Narrow gorges are developed in the hanging wall block of the Mishmi massif zone. It has also been noticed that most of the rivers form gorges of variable sizes just before crossing the scarp zone of the Mishmi Thrust.

Some of the rivers in the studied region also showed formation of strath terraces in the hanging wall of the Mishmi Thrust. Strath terraces are formed when a river incises the quaternary sediment cover and the underlying bedrock to a considerable extent.[13,20] This study also hinted at bedrock incision due to tectonic upliftments.

Bedrock incision near the thrust segments in the Mishmi Hills during the Quaternary period is a manifestation of tectonic activity. Bed incision is a process usually aided by enhanced climatic conditions or tectonic upliftment.[19]

Collectively, the field observations, the seismic data and geomorphic indices suggest moderately to highly active tectonics of the studied area (Fig. 9).

Past and Future Implications of Seismic Events: The northeast region is one of the most seismically active regions in India, with frequent occurrences of large earthquakes as demonstrated by historical records. The Mishmi Hills witnessed one major earthquake called the 1950 Great Assam Earthquake, which was the largest continental event ever recorded instrumentally.[2,6,7] Measuring M_w 8.7 in the Richter scale, the earthquake caused massive infrastructural destruction in several parts of Assam and Arunachal Pradesh.

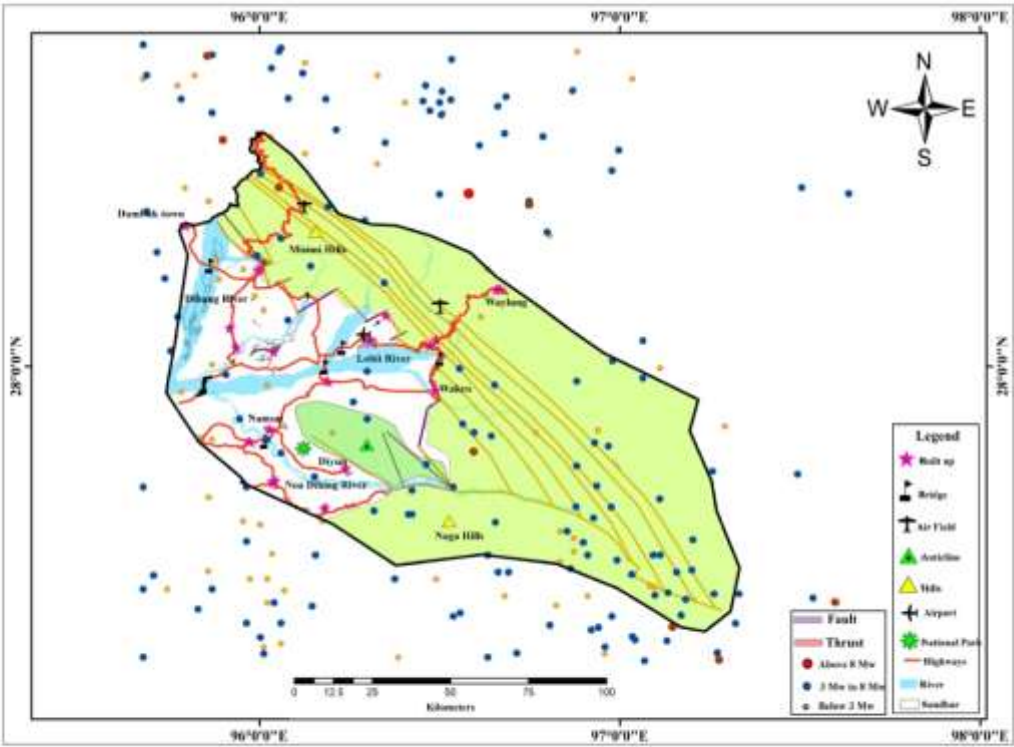

Fig. 9: Seismotectonic map of the study area

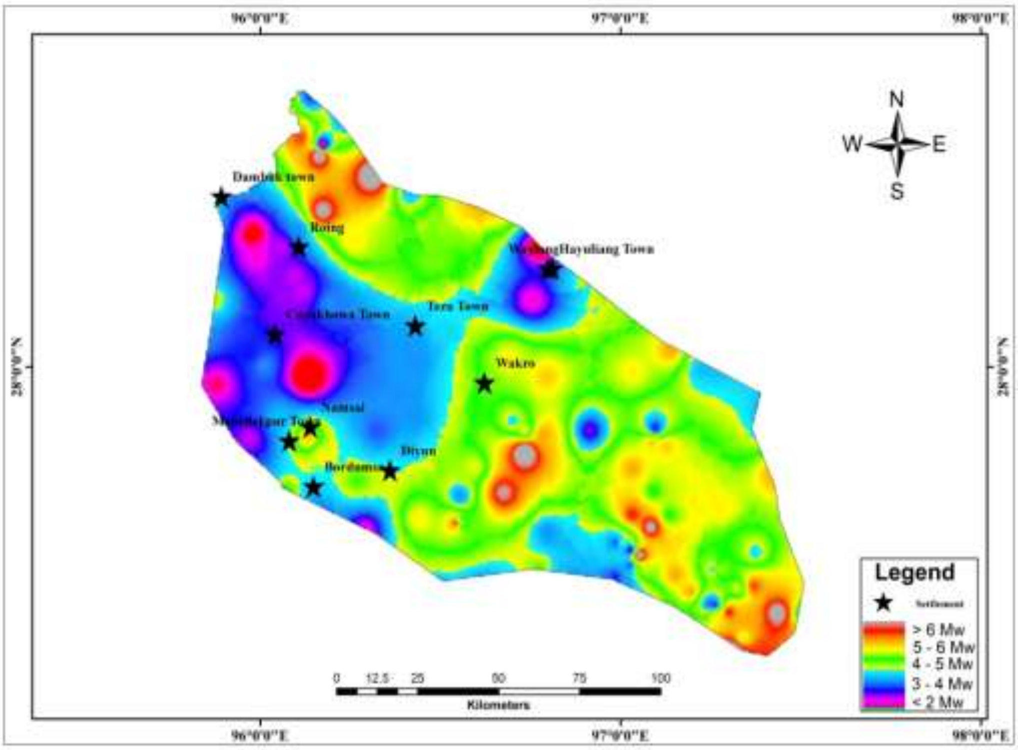

Fig. 10: Seismic Hazard map of the frontal part of Mishmi Hills

There were abrupt changes in the levels of valleys and plains and river beds after the 1950 earthquake. The earthquake triggered landslides that formed temporary natural dams and obstructed the course of three major rivers of the study areas. These temporary dams later burst, bringing down slit and excess water downstream. The Dibang River changed its old channel and caused havoc along the new channel completely destroying the erstwhile Sadiya town.[30]

To prepare for such earthquakes in the future, the study analyzed the infrastructure developments in the region. There are many towns in the region with multi-storied buildings that have been constructed without following the standard building codes of India. There is also a 2,880 MW hydroelectricity dam under construction in a high tectonic active zone in the region. Another major earthquake resembling that of the 1950's stands to inflict great socio-economic devastation to the region.

This study attempts to evaluate the seismic hazard of this region with an emphasis on the thrust zones. The seismic hazard of the Mishmi frontal part was evaluated by constructing and analyzing a hazard map (Fig. 10) that is based on seismic data and faults present in the area. Studying the current geology and tectonics identifies the area as a hazard zone and indicates potential large earthquakes in the near future. Hence, studying the area systematically for hazard analysis and proper land use plan is of outmost importance.

a. Site of Dibang Hydroelectric Power Project on Mishmi Hills

b. Extensive fold in quaternary deposits of Mishmi Hills is direct evidence of active tectonics

c. Neotectonic activity: terrace deposit above quartzite rock in Mishmi Hills

d. Youthful scrap of Mishmi Hills

e. Triangular facets in Manabhom Anticline are signatures of youthful nature of scarp in tectonically active terrain

f. Five level of unpaired Quaternary terraces along the left bank Lohit river in Parasuram Kunda

g. Buildings in Namsai town: Designed without following the BIS Code

Fig. 11: Field evidences

Conclusion

Morphometric analysis and seismic studies were carried out in the Mishmi Hills and its foothills located in Arunachal Pradesh and Assam (India) respectively to evaluate the seismic hazard potentiality of the area. Here, S_{mf} values identify the whole study area as moderately active; S values indicate the area as tectonically active; V_f observation indicate that the mountain is highly active; B_s calculations suggest elongated basins, indicating active tectonics; SL analysis puts all anomalous points in thrust zones; AF calculations reveal basin asymmetry and active tectonics; and T calculations reveal active tectonics in the area.

Thus, all the geomorphic parameters suggest high rate of incision associated with tectonic upliftment. Computing five parameters (S_{mf}, V_f, SL, AF, Bs) gave IAT values between 2.17 to 2.46, classifying the complete study area under IAT Class 3 i.e. moderately active zone.

Rose plot indicates that the major trends of the lineaments are aligned in the NW-SE and NE-SW direction. These trends are parallel to the thrusts and cross faults present in the area indicate the tectonic activeness of the zone. The estimated characteristic intensity is found to be in agreement with the local geology. Based on historical data and faults present in the area, both the alluvium and the hills are found to be seismically active. The study hints that the thrusts present in the Mishmi Hills can be the source of high-magnitude earthquakes in the future. Among the administrative areas under this study's purview, Roing, Tezu and Namsai towns in Arunachal Pradesh and Chapakhowa town in Assam are rapidly urbanising with several residential and commercial buildings built without compliance to proper engineering concepts.

Additionally, Roing and Wakro towns and the under-construction dam on Dibang River (all in Arunachal Pradesh) lie above thrust zones. In the event of any earthquake similar to that of the 1950's, the above-mentioned areas are likely to witness severe destruction. The scenario hazard map prepared in this study classifies the earthquake potentiality of different places in the study area providing a suitable basis to plan infrastructural developments to resist probable earthquakes and minimize potential losses.

It can be concluded that although the IAT values in the present study reveal moderately active tectonics but the individual parameters studied reflect the area as tectonically active. The thrusts present in the study area is bearing an under rated source of future earthquake, so in developing infrastructural projects, caution should be taken.

Acknowledgement

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