

Probabilistic Seismic Hazard Assessment for the Frontal Part of the Mishmi Hills, India and Its Role in Disaster Management



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Abstract Natural hazards can cause serious disruption to societies and their impact is highly dependent on the resilience of the communities. Normally, earthquakes strike without notice and can be recognized by a variety of direct and indirect impacts, as well as significant damage in a relatively short period of time when compared to other fast occurring natural catastrophes. Seismic hazard assessment is an important tool in any engineering planning, which aims to quantify the estimation of ground shaking hazard of a specific area to mitigate the impact of future disasters. This area is prone to earthquakes on a regular basis, and it was the hardest hit by the earthquake of 1950. Its initial shock measured was of magnitude 8.6, followed by many after-shocks. The purpose of the study is to help the society of the area and to address the vulnerability, mitigate hazards and prepare for response and recovery from hazard events. In the present day study with the help of geographical information system (GIS), the geological maps are processed and the hazard maps are assessed with the help of CRISIS-2007 software. Evaluation of the reliability of the proposed study was performed through uncertainty analysis of the variables used for producing the final output. The findings revealed that the high hazard zones are mainly distributed in the northeastern part of the area under investigation. The preparedness and prevention of an area are very essential for the response and rescue, so the study would be helpful in assessing the seismic hazard of the area so that it would be useful for the

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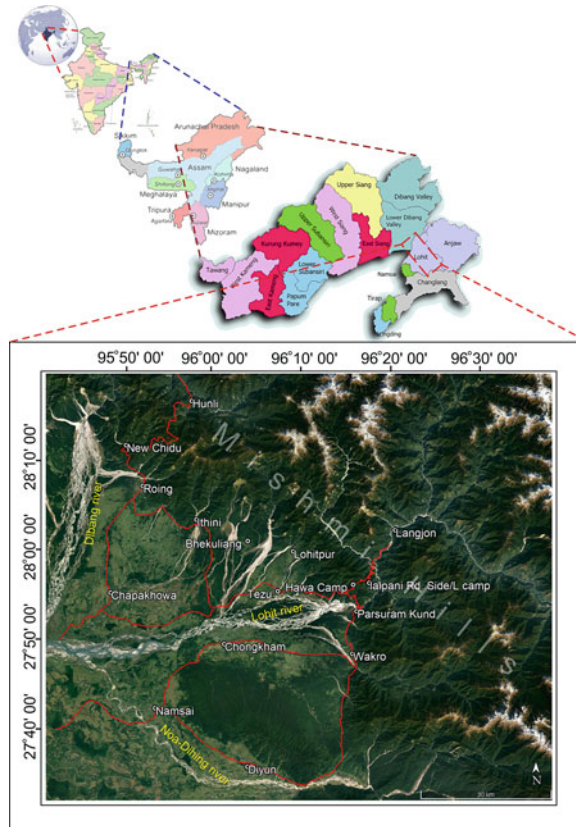
administration in earthquake hazard management and also use of proper safe standard structures may prevent loss of life and property, especially in the third world countries which are in seismically active zones.

Keywords Seismic hazard · Mishmi Hills · CRISIS-2007

1 Introduction

The tectonic history of the Mishmi Hills is connected to the upliftment of the Naga-Patkai Hills and the eastern Himalayas. The Mishmi Hills are located in the northeast direction of the Upper Assam Shelf and follow the trend of the Himalayas into China (Fig. 1). It has a significant role in the structural evolution of the northeastern region of India. There are several faults and thrust present in the Mishmi Hills (Gururajan and Choudhuri 2003). The Mishmi block is sliced transversely by many thrusts. Active

Fig. 1 Location map of the study area



Mishmi thrusts in the Mishmi Hills are discontinuing in nature and are dissected by transverse faults, making them tectonically active (Gogoi and Bezbaruah 2021).

As per the seismological map of the region, the area falls under zone V (BIS, 2004). The area is known to experience disastrous shallow-focus earthquakes (Tiwari 2000). The primary cause of this area's high seismicity is its geological movement, which has resulted in constant uplift resulting in the formation of mountains, hills, valleys and plains. These relative movements occur along deep fractures. Hence, earthquakes occur in this region due to the sudden movement along the faults. In the study area, there have been a few significant earthquake tremors. The Mishmi Hills witnessed one major earthquake, called the 1950 Great Assam Earthquake, which was the largest continental event ever recorded instrumentally (Ben-Menahem et al. 1974; Coudurier-Curveur et al. 2020).

Sadiya, Roing, Tezu and Namsai are towns situated in the frontal part of the Mishmi Hills. They are located in the easternmost part of the northeast Indian states of Assam and Arunachal Pradesh. The construction of Bhupen Hazarika Setu improved the communication between these two states and nowadays fast and unplanned constructions in these border towns are witnessed. The 1950 earthquake damaged a large number of buildings, roads, bridges and railway lines in these aforementioned towns. The earthquake caused abrupt shifts in the levels of the valleys and plains. Furthermore, flooding occurred in the study area due to a 1–2 m increase in river beds.

The area's current geology and tectonics have been identified as a hazard zone, indicating the possibility of significant earthquakes in the future. These towns are situated on both plains and hilly terrains and therefore have to face space constraints for construction purposes. Many towering buildings, including residential and commercial facilities, have been constructed in these towns without sufficient design and seismic analyses. This creates the necessity to assess the status of seismicity in the region realistically. Another major earthquake resembling that of the 1950s if stands it may create great socioeconomic devastation to the region.

Probabilistic Seismic Hazard Assessment (PSHA) parameters such as uncertainties in the earthquake location, its size and rate of recurrence and the variation of ground motion properties with earthquake location and size are considered. As uncertainties can be properly recognized, quantified and accumulated in a rational manner in the PSHA method, it, in turn, provides a better prediction of seismic hazards (Cornell 1968; Algermissen et al. 1982). In this study, the PSHA method has been used to analyse the seismic hazard assessment which is important to minimize the loss of damage to infrastructure and life in seismically unstable regions.

Following the study gap of the region, the objective of the paper is to understand the seismic risk of the entire frontal part of Mishmi Hills with the help of PSHA. And the mitigation measures to minimize the potential loss from future earthquakes are also discussed in this study.

2 Study Area

The Mishmi Hills are situated in northeast India, tectonically separating the Eastern Himalayan and the Indo-Burmese (Myanmar) mobile belts, thus forming a linkage (Nandy 1976). The rivers Noa Dihing, Dibang and Lohit are remarkable in the research region because they are geologically unstable and have high seismicity. Because of the presence of faults in the Mishmi Hills, the geology of the studied region is tectonically unstable. Geologically, the Mishmi block is divided into multiple distinct belts. All these lithotectonic belts are trending in the NW–SE direction and dipping towards NE.

Towards the south-western direction of the Mishmi Hills, the “Mishmi Crystalline is thrust above the alluvial plains along the Mishmi Thrust. Towards the north direction of the Mishmi Crystalline, the Tidding Formation over thrust the crystalline along the Tidding Thrust and gradually overthrust by rock of Lohit Plutonic complex along the Lohit Thrust” (Misra 2009). The Mishmi Crystalline is divided into two groups of rocks, which include the Lalpani Group predominantly consisting of garnet grade rock and the Sewak Group consisting of greenschist facies metamorphism. The abrupt change of grade of metamorphism was demarcated by the Lalpani Thrust and the Hawa Thrust. “An intra-formational thrust namely Hakan Thrust is present between the Lalpani Thrust and the Hawa Thrust, which falls under the Lalpani group of rocks” (Gogoi and Bezbaruah 2021). Furthermore, between the Lalpani Thrust in the south and the Tidding Thrust in the north, the central crystalline is of high-grade metamorphism of Mayodia Group. Along with the major features, Manabhum Anticline is also witnessed in the region, which comprises the Tipam and Dihing Group of rocks (Fig. 2).

3 Materials and Methods

Field surveys were carried out to gather the information that was used to create the study’s geological map. Brunton Compass was used to determine the direction and dip values of the various beds. The geolocation of the stations was obtained using the global positioning system (GPS).

The ArcGIS modelling approach was used to create the earthquake zonation map (Fig. 3). Data from NEIST, USGS and IMD were being used to generate historical earthquake data from 1950 onwards. Since the magnitude scales of the three institutions differ, the data in this research was translated to Mw using mathematical relationships (Scordilis 2006).

The CRISIS software package has been used in this work to calculate the seismic hazard in a given area for the Mishmi Hills. Selection of source and site, the inclusion of source seismicity, spectral ordinates, consideration of current attenuation models and selection of global parameters were the approaches employed step by step for evaluating seismic hazards through CRISIS-2007.

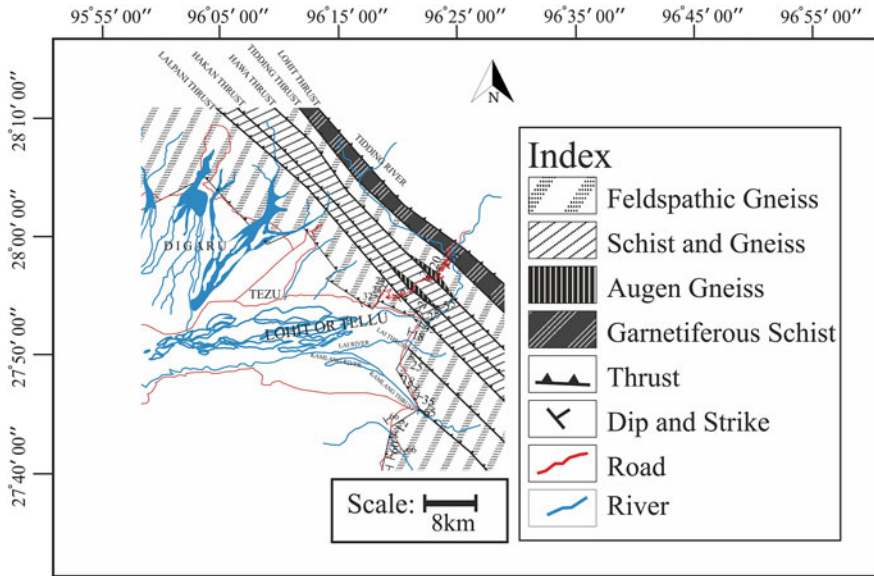


Fig. 2 Geological map of the study area

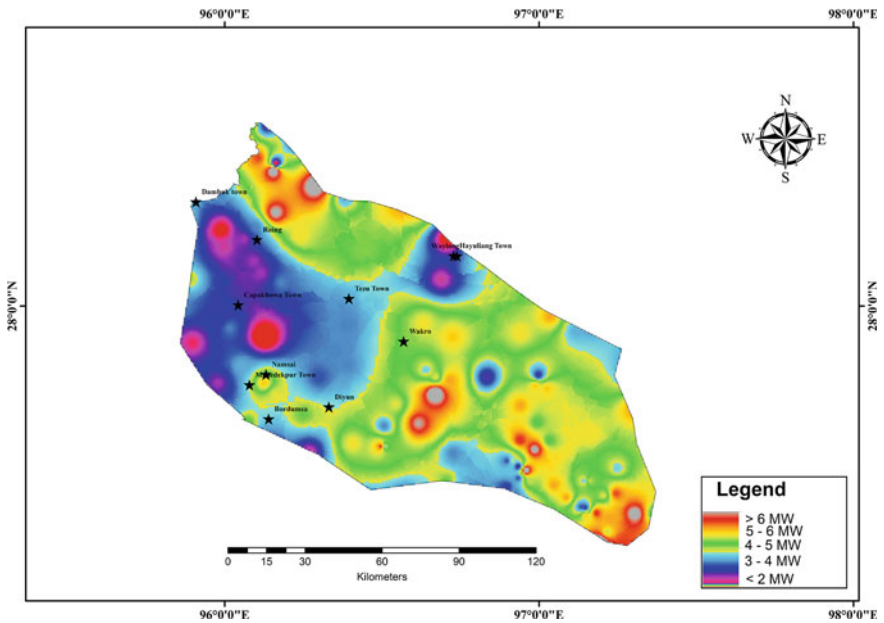


Fig. 3 Earthquake zonation map

4 Analysis

The PSHA for the concerned area estimates the variations in the probability of the exceedance of various parameters within a timeframe for different structural periods. For the study area, the hazard map shows variability in peak ground acceleration (PGA) over a timeframe. Certain structural periods were computed for four different towns, viz., Sadiya, Tezu, Namsai and Roing of the study area. Accordingly, the hazard curves show the probability of exceedance of certain PGA values for the defined structural periods. The input steps in CRISIS-2007 are as follows.

4.1 Selection of Source and Site

The study area is divided into grids of $0.165^\circ \times 0.165^\circ$. Four potential source zones were taken into consideration for the study: the Tulus fault, the Mishmi thrust zone, the Hakan thrust and the Tidding thrust. The zones were digitized using the ArcGIS 10.3, and input was provided to the CRISIS-2007 along with other parameters such as depth and fault mechanism.

4.2 Inclusion of Source Seismicity

In CRISIS-2007, the time-independent Poisson's model was used to define source seismicity. In the Poisson's model, while dealing with the shape of the curve for the exceedance rate of earthquake magnitude for a specific return period, parameters such as λ_0 , β , μ and M_0 are extremely important. For all source zones, the seismic pattern was defined and slip rate and slip movement were calculated as shown in Table 1.

4.3 Spectral Ordinates

Spectral parameters are defined as the parameterization of a total number of different intensity measures for which hazard is to be calculated. Between the limits of 1 gal (cm/s^2) and 1,000 gal, different levels were chosen, for which the exceedance probabilities were computed. The intensity measures refer to spectral ordinates for different structural periods, which are represented by the rate of exceedance (1/year) versus PGA (gal), for which the hazard scenario is to be estimated.

Table 1 Calculation of slip rate and movement

Parameters	Fault zone			
	Tulus fault	Mishmi thrust zone	Hakan thrust	Tidding thrust
Length (km)	25.31	97.44	168.18	188.95
Depth (km)	20	4	14	22
Threshold earthquake magnitude (M_0)	4	4	4	4
Exceedance rate of earthquake (λ (M_0))	3.8	4.3	4.8	3.1
Expectation of b-value (β)	0.48	0.5	0.4	0.4
Coefficient of variation of b-value $E < \beta >$	0.05	0.05	0.06	0.05
Untruncated expected value as the maximum magnitude	6	8.6	8.6	8.6
Untruncated standard deviation of the maximum magnitude	± 0.1	± 0.1	± 0.1	± 0.1
Lower limit of the maximum magnitude (M_1)	4	6.5	6.5	6.5
Upper limit of the maximum magnitude (M_2)	6	8.6	8.6	8.6

4.4 Consideration of Existing Attenuation Models

The CRISIS platform needs a file for specific attenuation law that is to be implemented for calculations while dealing with the attenuation of seismic intensities. For each attenuation characterization of seismic intensities, each file contains the table of values with parameters such as focal depth (in km), magnitude, various measures of intensities corresponding to each magnitude and focal depth, standard deviation of intensity values, period for the corresponding structural seismic intensity and the upper limit of intensity as an optional one. Two types of attenuation models are referred to in the CRISIS platform, viz., user models and built-in models. The user has to define the relationships among size, intensity and focal depth for a particular attenuation pattern in the user model mode. In this study, attenuation models were used to define three source fault models and the Mishmi frontal part model.

4.5 Selection of Global Parameters

For the approximation of earthquake recurrence with specified intensities, the global parameters selection option programme requires specification with certain return

periods. Map files were generated for four probable return periods, viz., 100, 200, 400 and 500 years. Other parameters involved are minimum triangle size, the approximate length of the fault and maximum integration distance in km from the site to responsible source geometry. Minimum ratio as the distance/triangle size and distance for M-R disaggregation as a function of magnitude and distance for different intensity levels of exceedance were used. Finally, for hazard calculation execution of the saved data was used.

5 Results and Discussion

In this study, ten structural periods were taken for hazard estimation, which are 0.0, 0.05, 0.10, 0.15, 0.3, 0.5, 1, 2, 3 and 4 s. The frequency of vibration taken along these periods is 0, 20, 10, 6.66, 3.33, 2, 1, 0.5, 0.33 and 0.25 Hz. In this study, the mode of vibration for the associated period 0 s or 0 Hz signified that there are no vibrations in the structure but the ground itself experiences the whole vibration intensity.

5.1 *Probability of Exceedance Versus Intensity: Hazard Curve*

This study furnished hazard curves indicating the probable rate or probability of occurrence of an event per year, which will generate ground shakes exceeding a specific value in gals (cm/s^2). Parallely, the specific amount of intensity will exceed at least once for the respective exceedance rate. It also signifies the number of such events that will occur per year. The hazard curves were computed at the centre of four towns (Sadiya, Roing, Tezu and Namsai), using structural periods 0.0, 0.3, 0.05, 0.1, 0.15, 0.5, 1, 2, 3 and 4 s for each of the towns. Figure 4a–d shows the graphs for the four towns.

5.2 *Hazard Maps for Different Return Periods*

Hazard maps are the representation of the probable hazard scenario of a large area. These maps represent the probable intensity that is likely to be exceeded within a fixed span of the return period. In this study, hazard maps were prepared for 0 s (Fig. 5a–d) and 0.15 s (Fig. 6a–d) for 100, 200, 400 and 500 years. These two specific structural periods were chosen because the period 0 s represents the free ground vibration without any structural motion, whereas the period 0.15 s is found to be associated with the maximum structural acceleration. The hazard maps clearly

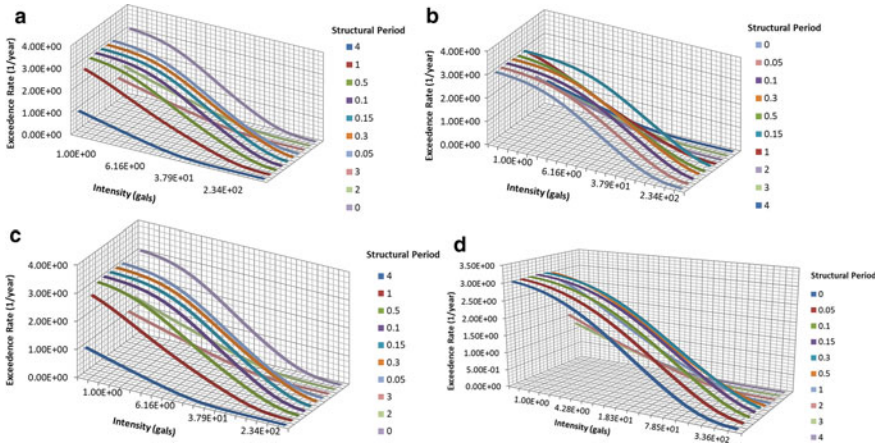


Fig. 4 Probability of exceedance versus intensity (hazard curve)

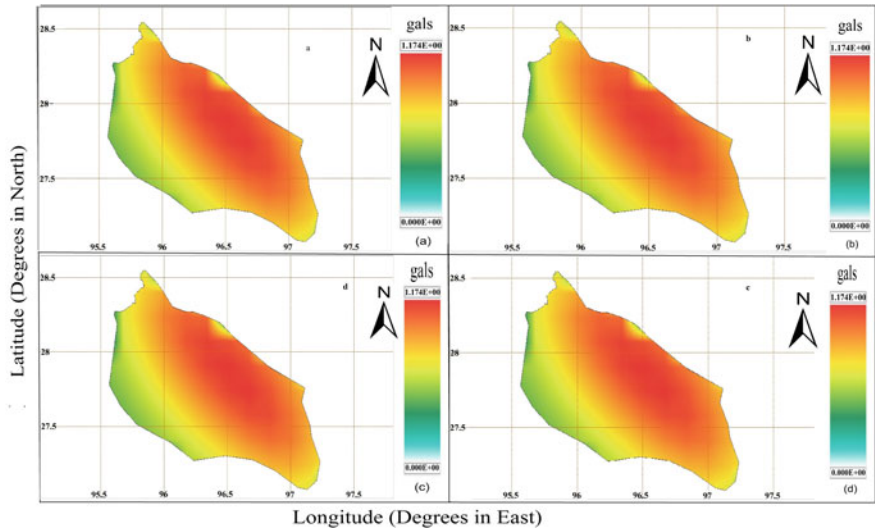


Fig. 5 Hazard map

show that the maximum amount of ground motion is towards the NE direction of the study area.

From the analysis of probabilistic seismic hazard assessment of four locations, viz., Sadiya town, Tezu town, Namsai town and Roing town, it has been observed that the exceedance rate decreases with an increase in intensity in gals for a particular value of the structural period. However, it is also envisaged that the exceedance rate is maximum at a particular value of 0.15 s structural period for the four locations, and it is also clearly highlighted that the probability of exceedance of a certain value

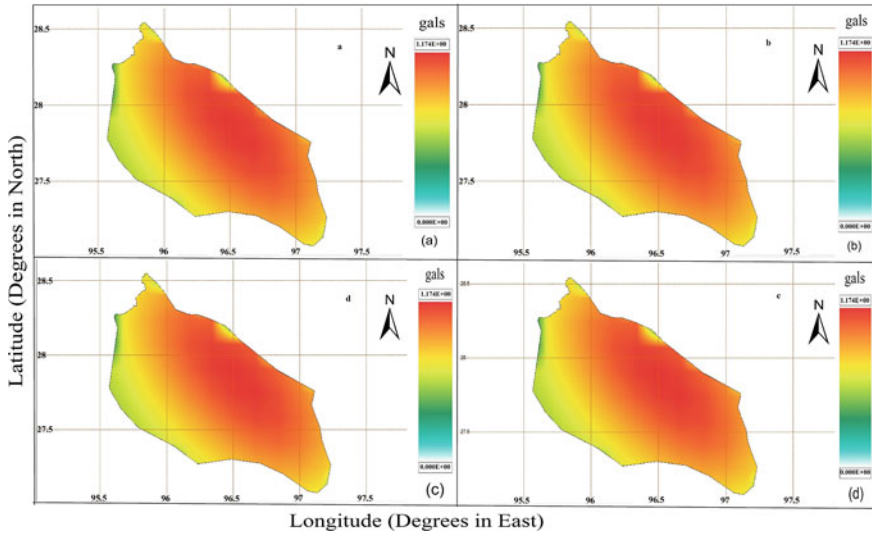


Fig. 6 Hazard map

of intensity is comparatively low for the maximum value of the structural period, i.e., 4 s. Therefore, hazard curves indicating the exceedance rates represent the prior information for a possible scenario, which is likely to occur in a specific time period.

Hazard maps represent that the distribution of probable intensities may exceed within specific return periods of 100, 200, 400 and 500 years for structural periods of 0.0 and 0.15 s. The seismic hazard map of the study region shows that the distribution of intensity (gal) may exceed in a return period of 100, 200, 400 and 500 years for the structural periods of 0.0 s. The seismic hazard assessment suggests that most of the areas towards the NE of the study area are under a higher amount of menace potential to be foisted by the effect of the major thrusts present in the Mishmi Hills.

6 Role of PSHA in Disaster Management

An earthquake is only a natural disaster, which cannot be predicted till now with 100% accuracy. Due to past seismic events and potential hazards from earthquakes, the entire region has been included in the severe seismic zone. The Probabilistic Seismic Hazard Analysis (PSHA) tool is used to reduce and control the hazard. The development of this model can assess the uncertainties in earthquake size, location and time of occurrence. The methodology can be used in any region to carry out the investigation into earthquake prediction, estimate the seismic vulnerability of public and private properties, and may be extended to assess the impact of earthquake mitigation measures.

An increase in haphazard construction has been noticed in the studied towns, which is also considered one of the major factors that increase the vulnerability. The vulnerability study may be given special importance with reference to commercial buildings, hospitals and schools, roads, electric supplies and communication. It is also important to identify safe zones and structures as relief centres in any incidents of future disasters.

7 Conclusion

The study attempts to establish relationships between enhanced seismic vulnerability and natural and anthropogenic activities in the area. Based on historic earthquake data, the area is considered to be seismically active. This study hints that the thrusts present in the area can be the source of high magnitude earthquakes in the future. Such events could manifest aggravated damages since human settlements in the area are rapidly growing without adherence to proper engineering concepts. Therefore, the research concludes that the area is seismically active and there should be diligence in adopting engineering designs for developing infrastructure, which may include commercial or residential properties.

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