CHAPTER - 2
GEO-TECTONIC SETTING AND SEISMIC HISTORY OF NORTHEAST INDIA AND ITS ADJOINING REGION

2.1 Geographical Outline

The northeastern part of India has a fascinating diversified landscape having valleys and razor-edged high hills, snow clad mountains and meandering rivers, flat high lands, deep gorges and waterfalls (Figure 2.1). This region is called the “land of blue hills and red rivers” due to its misty forested hills and silt laden river water in the monsoon. The narrow and relatively densely populated Brahmaputra Valley, the life centre of the region, evolved during the last two million years through subsidence and alleviation of the foreland depression is in between the young mountain chains of the Eastern Himalaya and Indo-Burmese (Myanmar) mobile belts and the block-uplifted plateau of Meghalaya.

The seven states of Assam, Nagaland, Mizoram, Meghalaya, Manipur, Tripura and Arunachal Pradesh comprises Northeast India and occupy 2,54,979 sq km of mostly mountainous terrain of which 65% is under dense forest cover. This region is connected to the rest of India only through a narrow corridor (50 km wide) of northern Bengal. About 98% of its borders are with neighbouring countries namely China, Bhutan, Myanmar and Bangladesh (Figure 2.2). In spite of the fact that the seven states endowed with considerable natural resources such as 37% of country’s river water, 20% of the hydro-carbon potential, large quantities of low ash, high sulphur coal resources and huge reserve of limestone and dolomite, the region remains largely underdeveloped because of its inaccessibility. Even then, the Northeastern state of Manipur is mentioned in the Mahabharata. Recent findings of burnt potteries and other archaeological artifacts near Guwahati indicate that the place was the seat of ancient civilization.
Fig. 2.1: Satellite Imagery of Northeast India and its adjoining region reflecting the topography of the region
2.2 Geo-tectonic Setting

Northeast India and its adjoining territories display tectonically distinct geological domains occurring in intimate spatial association as shown in Figure 2.3. The Eastern Himalayas is characterized by uneven, banded, massive, granular and blocky textures on satellite imagery. Large arcuate lineaments are characteristic. Rugged and uneven topography with prominent N-S fractures. NW-SE and NE-SW trending fractures are also common. Some of the prominent lineament cut across more than one tectonic domain. The important arcuate lineaments representing traces of the Himalayan thrusts take NE-SW to NNE-SSW trend in Subansiri and Siang districts of Arunachal Pradesh and terminate against the NNE Siang fracture zone. The seismic events are mostly concentrated along the MCT and MBT. The northeast corner is bounded by the Mishmi block. This block is characterized by rough uneven granular texture dissected into triangular and rectangular blocks; raised and rugged topography with straight, dendritic and rectangular drainage pattern. NW-SE and N-S lineaments are very common; but NE-SW and E-W lineaments are less important. The NW lineaments depict important structural elements like Tidding Suture, Lohit thrust, Mishmi Thrust and Po Chu fault. The Lohit Thrust and the Mishmi thrust is present in the area between the Siang Valley and the Nao-Dihing Valley. These two thrust dip in the easterly direction with dip angles 40°-70°. The Mishmi Hill occur at the junction of the Eastern Himalaya and Indo-Burma range. The Great Assam Earthquake (1950) occurred in the Mishmi Block. This event yielded both dextral slip along NW nodal plane and also thrust events.(Nandy, 2001). The Naga Hills is a part of Indo-Burma range and appear to consist of several thrust. Geological evidence indicates that the thrust movement in the Naga Hills area have taken place mostly from south-east toward north-west during upper tertiary times. In the north of Naga Hills, there are oil fields of Naharkatiya, Rudrasagar and Moran (Verma, et.al.,1973). Towards the southwest of the Naga Hills, the junction between the alluvium and the hills is marked by the thrust called the Naga thrust. The extension of the Naga thrust to the south-west is called Disang thrust which in turn extends as Haflong fracture zone and joins east-west striking the southerly dipping Dauki fault. The Disang thrust is about 500 km length which suggests that younger tertiary rocks have moved northward over older rocks.
Fig. 2.2: Northeastern region showing its seven states
Fig. 2.3: Map showing the major tectonic features of the study region (source: Evans and Krishnan, 1964)
Within the Naga hills there is a feature named Patkai Synclinorium. It is a broad area which is broken up by strike slip faults. There are several anticlines with over thrust faults on the Assam side of the Patkai range. To the south-south-west of Patkai Synclinorium, there is another synclinorium named Kohima which was a broad syncline with narrow sharply folded and faulted anticlines. This region merges into the eastern part of the Surma Valley. The Patkai and Kohima Synclinorium and their southward continuation into the Manipur and Arakan-Yoma belt form a part of the Indo-Myanmar range. The seismic events of magnitude greater than 6.0 mb are uniformly distributed with two events near the Naga thrust and one event at the Disang thrust.

The Indo-Myanmar and the Arakan-Yoma region is an elongated crescent shaped belt extending from the Bay of Bengal to the Mishmi Block in a N-S, NNE-SSW and NE-SW direction. It is characterized by parallel ridges and valleys, rugged and intensely dissected topography with parallel and dendritic drainage. Tightly appressed folds, parallel faults and parallel to sub-parallel traces of thrusts having arcuate pattern are common. The NE-SW and NNW-SSE lineaments and fractures are prominent. Some of such lineaments continue across the Upper Assam shelf to the northwest and Central Myanmar basin to the east. Imbricate fish-scale thrust sheets on the north-western side of the belt over the Upper Assam molasse basin and long arcuate thrust sheets to the eastern boundary zone of the orogen which include ophiolites and the mélange are important. To the extreme east the Eastern Boundary thrust delimiting this mobile belt from the Central Myanmar basin forms an important structural element for the origin of this outer arc ridge. Towards the east is the Sagaing Fault which is a major fault in Myanmar and is a continental transform fault between the Indian plate and Sunda Plate. Its length is over 1200 km and its right lateral slip rate is 18mm/year. The Sagaing fault has been dormant since 1946. The 1988 earthquake of magnitude 7.1mb has its epicenter near the Eastern Boundary Thrust.

Surma Valley is a zone of folded sediments and is characterized by westerly convex, sinuous structural ridges and valleys of low relief having first order topography. This basin is wider to the north and narrower to the south. The structural grains of different long and linear anticlines with their corresponding synclines all over the basin can be mapped. The NE-SW and NW-SE lineaments/faults are very common.
The NE Sylhet lineament/fault running from near Dhaka, Bangladesh to the northeastern corner of the Bengal basin demarcates the northwestern boundary of the valley. This structural feature initially identified as the lineament (Nandy, 1980) was later mapped as a major fault through seismotectonic analysis (DasGupta and Nandy, 1982). Another NE trending lineament is the Gomti fault which cuts across the Bengal and Surma basins. There are many such NE lineaments/faults in the Southern part of the valley which show strike slip displacement of the fold axes along them. Along some of these transverse lineaments/faults the eastern basin margin fault of the Surma valley has been dislocated at places. Thus the valley has evolved under broad E-W compressive stress was first responded by a folding episode having broadly N-S axial planes and later by a faulting episode yielding conjugate sets of strike-slip faults with dextral and sinistral movement. Padma and Madhupur lineament of the valley seems to be seismically less active compared to other lineaments of Northeast India. All these sets of lineament run parallel to the Tista lineament. The low seismic activity in the region suggests that this region has almost reached near isostatic equilibrium. The crust of the valley must be very thin (Verma and Gupta, 1973), hence isostatic equilibrium is reached even after the deposition of thick sediments by the Ganga-Brahmaputra basin.

The Shillong Plateau lies roughly in the E-W direction between the Brahmaputra Valley and the Surma Valley together with the Bengal Basin. This plateau is surrounded to the west by the Yamuna Lineament and to the east it is covered by the tertiary sediments of Upper Assam and also Kopili Lineament. Mikir Hills is also towards the east of the plateau. The geological feature reveal a criss-cross pattern of faults cutting the ancient rocks of the basement. The faults Chedrang and Samin fault reported by Oldham appear to be still active (Sarmah and Deka, 1987). The Shillong Plateau is separated from Bengal Basin by a dextral transcurrent fault known as Dauki fault (Evan, 1964). There are several faults north of the main Dauki fault. There is considerable variation in the depth of the faults. The faults in the northern part are shallower. The Dauki fault appear to be a major line of weakness in the crust. The Dauki fault merges with N-E trending Disang thrust which is about 500 km in length upto Upper Assam (Verma et. al, 1973). The N-S Dudhnai and Kulsi lineaments/faults are very prominent. They cut across the plateau and extend on either side in the Sylhet
plain and Brahmaputra Valley. The earthquake of magnitude 8.7 Ms that occurred in June, 1897 had its epicenter here. It is seen that seismic events are distributed in and around the Dauki Fault.

The Brahmaputra valley lies between the Eastern Himalayas and the Naga Hills. The Shillong Plateau and the Mikir Hills are situated in the southern boundary of the valley. The valley is connected to the vast Indo-Gangetic basin to the west. The Brahmaputra valley is at present covered with alluvium and upper tertiary sediments estimated to be about 4-6 km in places. The WSW-ENE Brahmaputra lineament represents a deep seated fault (DasGupta and Nandy, 1982). The NW-SE Kopili lineament (Nandy, 1980), later identified as the Kopili fault (DasGupta and Nandy, 1982) is an important active tectonic feature lying in between the Meghalaya Plateau and the Mikir Hills. NW Bomdila fault demarcates the northeastern boundary of Mikir Hills. Statistical analysis of the lineaments shows a broadly NE trend over the Meghalaya Plateau and the Mikir Hills. The NW-SE Kopili fault zone produced the 1869 Cachar (M>7.5) and 1942 (M>7) earthquake events. The Bomdila fault has also generated quite a few earthquakes through strike-slip motion.

2.3 Geology

The physical features of the region is given in Figure 2.4. The Himalaya form the most complex orogenic belt in the world. Rocks representing the entire span from archean to recent occur in this very small region. Eocene (Disang) sediments of trench facies occur in juxta-position with those of platform facies (Jaintia) of stable shelf condition. Neogene Siwalik foredeep molasse in front of the Himalaya and Tipam molasse of Upper Assam basin in front of the Indo-Myanmar mobile belt occur in close proximity which are separated by the Brahmaputra alluvium. Proteozoic to early Paleozoic intrusive granites are common in Meghalaya Plateau, while Tertiary granites are found in the upper reaches of the Eastern Himalaya. Upper Jurassic Cretaceous and multi-phase effusion of volcanic rocks are exposed in the Meghalaya Plateau. The Abor volcanic of Upper Palaeozoic to Eocene age from the Eastern Himalaya indicates episodic and protracted volcanisms. Upper Cretaceous mantle derivatives (carbonites and ultramafics) in the Meghalaya Plateau and Mikir Hills, and the admixture of continental and marine Gondwana rocks in a narrow belt along the
foothills of the Eastern Himalaya represent early stage of rift-drift tectonism during disintegration of East Gondwana land, which was eventually followed by convergent tectonism at the two (i.e. northern and eastern) leading edges of the Indian shield. The two resultant young mobile belts disposed almost at right angles to each other (viz. E-W Eastern Himalaya and N-S Indo-Myanmar mobile belts) meet at the northeastern corner of India; but the original character of the junction has been overprinted by NW trending Mishmi block, which now, forms the orographic linkage between the mobile belts.

The basement complex of Meghalaya Plateau occupies a crucial position in that it is bordered to the north by a collision milieu and on the east by a subduction milieu. Thus, Northeast India and its adjoining region has the geological features that characterize both convergent tectonism in the north and subduction tectonism in the east including fossil rift settings that preceded plate convergence. The relief of most of the hills in the study region varies from 130 meters to 1610 meters above mean sea level. In the Eastern Himalaya, Mio-Pliocene foredeep molasse (Siwalik) forms the sub-Himalayan zone, followed to the north by para autochthonous continental and marine Gondwana sequence thrusted over the Siwaliks along a moderate to steep hinterland dipping thrust (Main Boundary Thrust). Gondwana outcrops continue as a thin belt from eastern Nepal to Siang river section in Arunachal Pradesh and are tectonically overlain by the orthoquartzite-dolomite sequence of Buxa and low grade parametamorphites of the Daling Sequence of the Lesser Himalayan zone. The Lesser Himalayan litho-tectonic units in turn are tectonically overlain by the Central Crystallines along another extensive north dipping thrust (Main Central Thrust).

In northeast India the Mishmi block occur along the E-W Noa-Dihing Valley of Arunachal Pradesh. The geological features bordering the Indian sub-continent (Indo-Myanmar arc) to the east have resulted from the northeastward drift of Indian continent and its collision with the Shan-Tenasserim block of the Asian landmass by early mid Eocene. The contact of Mishmi block and the Indo-Myanmar arc is marked by the WNW-ESE Mishmi Thrust dipping NNE. The geological features characterizing the Indo-Myanmar arc are the outer arc ridge of the Indo-Myanmar range and the Andaman-Mentawai arc representing the Palaeogene subduction-accretion complex at the leading edge of the Indian plate.
Fig. 2.4: Physical map of the study area
In this area, several dismembered ophiolite bodies and exotic blocks of metamorphic and mesozoic rocks occur along the seaward flank of the forearc trough forming a well developed forearc basin that extends from Chindwin valley in north Myanmar to the Mentawai trough off Sumatra. This magmatic arc extends from the Jade Mines in north Myanmar to Narcondam-Barren volcanic islands forming a narrow linear faulted backarc basin between the magmatic arc and the west Kachin unit (Shan-Sagaing fault). The overriding southeast Asian continental block includes the west Kachin unit of northeast Myanmar and isolated basins of Neogene accretionary prism or subduction accretion complex occurred to the west of the Palaeogene outer arc ridge.

The Surma valley includes the world’s largest delta formed by the Ganga-Brahmaputra river system which is mostly covered by alluvium. To the west, it is bounded by the Rajmahal hills and the extension of Chota Nagpur Plateau. To the east, it is delineated by the fold belt of the surma basin and it is bounded by the Meghalaya Plateau to the north. It extends into the Bay of Bengal in the south. It was found that a complete Tertiary sedimentary sequence lies under the Bengal Alluvium of Pleistocene recent age. The sediments gradually thicken eastward from about 1,200m near the basin margin in the west to about 12,000m in the deeper part of the basin in West Bengal. However, the maximum thickness encountered in the deepest part further to the east in Bangladesh exceeds 20,000m. The valley can be subdivided into North Bengal Foreland consisting of E-W Rangpur Saddle and the Balurghat Bulge and its northern slope, N-S to NE-SW basin margin fault zone with en-echelon down to basin faults and scarps, the Stable Shelf with homoclinal dip towards east and southeast located on the east of the fault zone, elongated ‘S’-shaped Hinge Zone showing conspicuous basin-ward flexure and the deep basin lying east and southeast of the Hinge zone.

The Meghalaya Plateau and the Mikir Hills occur in between the E-W Eastern Himalaya to the north and the broadly NNE-SSW Indo-Myanmar mobile belt to the east. The northern and northeastern boundary with the Bengal basin lies to its south. These geological domains are separated from the main Himalayan belt by the Brahmaputra alluvium. The Mikir Hills are separated from the Meghalaya Plateau by the alluvium tract of the Kopili river and the NE-SW Kopili fault. The Mikir Hills represent a peneplaned surface of gneissic rocks later covered by the sediments along its southern and eastern flanks. The Kernel of the plateau and the hills is the Archean-
Proterozoic Shillong Group, late tectonic Proterozoic Khasi greenstone and Proterozoic early Palaeozoic porphyritic granite. Isolated intrusions of ultrafamic carbonatite complex of late Cretaceous age occur along a NE lineament over the plateau and the hills. Part of the southern margin of the Meghalaya Plateau is covered by the Jurassic-Cretaceous basaltic trap. Southern fringe, southeastern and south-western part of the basement complex is covered by platform sediments exposing rocks from Cretaceous to Holocene age. The Brahmaputra valley is mainly a Quaternary fill valley with a few isolated sedimentary residual hills in upper Assam and inselbergs and hills of gneissic rocks in the Darrang, Kamrup and Goalpara districts. The tertiary group of rocks of the area has been classified into Disang group, Barail group, Tipam group and Dihing group from oldest to youngest.

2.4 Seismic History

Seismically, northeast India is one of the six most active seismic regions of the world. According to the seismic zonation map of India the region is placed in the highest zone i.e. zone V. Earthquakes up to intensity of IX (Modified Mercalli Scale) can be expected. According to the hazard map prepared under the Global Seismic Hazard Assessment Programme, the state can expect to have a peak ground acceleration (PGA) of 0.24g to 0.48g.

Historical records are replete with references of catastrophic earthquakes that caused large scale damage to lives and properties in the Northeastern region of India; but in the absence of instrumentation, the magnitude of these earthquakes cannot be authenticated. A huge earthquake is stated to have occurred during the reign of king Suklenfa of Ahom kingdom in 1548. The successive rulers of Ahom kingdom Sukhamfa, Susnega and Sarufa faced earthquakes in 1596, 1601 and 1642 respectively. The earthquake of 1663 was so devastating that Mirjumla is believed to have fled Assam. The reign of King Rudra Singha experienced earthquakes twice in 1696 and 1749. There are historical evidences that earthquakes damaged parts of Assam in 1772, 1832 and 1848. As many as twenty destructive earthquakes of magnitudes 6-7 rocked this region during the past century. With the setting up of the Geological Survey of India in 1851, necessary instruments for measuring magnitude and intensity of earthquakes were deployed making it possible to study the occurrences
of earthquakes in a scientific manner. Since then hundreds of earthquakes of varying magnitudes and intensities have been reported from all over the northeastern region of India and as many as twenty destructive earthquakes rocked this region with damaging consequences.

The following is a brief summary of some of the major earthquakes of the Northeastern region of India.

2.4.1 The Cachar (Assam) Earthquake

The Cachar earthquake of 1869 was the first significant earthquake occurred in this region that was studied in a scientific manner. The earthquake of magnitude 7.5Ms struck on 10th January 1869 and had its epicentre located 9.4 km North of Kumbhidgram (25°N lat. and 93°E) in the Cachar region of Assam.

The impact of the shock was felt over 6,50,000 km². There was heavy damage in the towns of Cherrapunji, Silchar, Shillong and Sylhet and also in Manipur. Fissures opened on the banks of the Surma river and sand vents threw up great amounts of sand and water. The epicentral tract was 30-45 kilometres long and 5-6 kilometres wide lying on the northern border of the Jaintia Hills. The hypocentre had a depth of 50km. This is the first earthquake in India for which Geological Survey of India carried out field investigations. Sir Thomas Oldham carried out the investigations. A comprehensive report on the earthquake was published in 1882 as GSI Memoirs.

2.4.2 The Shillong (Meghalaya) Earthquake

This earthquake occurred on 12th June, 1897 and had its epicenter at 14 kms ESE of Sangik, Meghalaya (25.5°N lat. and 91°E long). It was one of the most powerful earthquakes in the Indian sub-continent. The quake wrecked havoc across south-west of the present states of Assam, Meghalaya and Bangladesh. About 1542 people were killed and hundreds more injured. Damage from the earthquake extended upto Kolkata, where dozens of buildings were badly damaged or partially collapsed. Shaking from the event was felt across India, as far as Ahmedabad and Peshawar. Seiches were also observed in Myanmar. It had a magnitude estimated variously between 8.7 Ms and 8 Mw.
The earthquake caused great destruction to many towns in Assam and Meghalaya, particularly Shillong and Guwahati, where many structures collapsed. For example, all stone works in the neighbourhood of Shillong, including most of the bridges, were absolutely leveled to the ground. The stone houses and particularly the Churches were reduced to flat heaps of rubble. Two 30-40 ft tall monuments of excellent cut stone work were ruined. Ekra-built buildings also got damaged. Plank buildings of wooden framework and resting unattached on the ground remained intact. Landslides were reported all across the Garo Hills. The towns of Dhubri, Goalpara, Guwahati and Cooch Behar in Assam and West Bengal were heavily damaged. Earthquake fountains, some 4 feet high, were reported from Dhubri. The Jolboda and Krishnai bridges were also ruined. At Goalpara, a 10-foot wave from the Brahmaputra (possible subsidence), swept into the area, destroying the bazaar and many pukka buildings. Ground waves were reported from Nalbari, where an observer saw rice fields rise and fall as the waves passed under them. At Guwahati, the earth subsided along the Brahmaputra and several sand vents were formed. The Brahmaputra is also reported to have risen by 7.6 metres and even reversed its flow during the shock. Large scale subsidence was also reported from Muktagacha, Bangladesh. This town was constructed on reclaimed ground. Fissures and sand blows occurred over a wide area of Assam, Meghalaya, West Bengal and northern Bangladesh. Fissures and sand blows were also reported from some parts of Bihar.

The earthquake affected both Dhaka and Kolkata. In Dhaka many buildings collapsed, many more were heavily damaged. Sand vents also occurred at many places in the city. Kolkata was also badly affected, though to a much lesser extent than Dhaka. Walls and parapets came off many buildings, and the steeples of some churches were broken off. Damage was reported from Bardhwan, Bhagalpur, Behrampur, Comillah, Chittagong, Jamalpur, Jessore, Khulna, Monghyr (Munger), Murshidabad, Naokhali (Majid) and Purnea.

2.4.3 The Meghalaya Earthquake

A strong earthquake shook parts of south of Meghalaya, Assam, West Bengal and Bangladesh on the morning of 9th September 1923 with its epicenter at South Meghalaya (25.5° N lat. and 91° E long.) and of magnitude 7.1Ms. The earthquake
caused heavy damage at Mymensingh, Cherrapunji, and Guwahati. The earthquake was also felt at Barisal, Chittagong, Nagrakata, Midnapore, Srimangal, Sivasagar, Tatung, Salonah, Borjuli, and Narayanganj.

2.4.4 The Dhubri Earthquake

Another strong earthquake shook parts of western Assam, West Bengal and Bangladesh on the morning of 2nd July 1930 with epicenter at a distance of 3.9 kms NNW of Dabigiri, Meghalaya (25.8° N lat. and 90.20° E long.) and of magnitude 7.1 Ms. In spite of the fact that it hit in the early hours of the morning, the Dhubri earthquake however surprisingly did not cause any fatalities, though a few were injured. Most of the buildings in Dhubri and the surrounding areas were damaged in this shock.

2.4.5 The Hojai (Assam) Earthquake

At around 11 pm on the 23rd of October 1943, a major earthquake rattled northeast India. The shock had a magnitude of 6.9 Mw and had its epicenter at 13.6 kms east of Hojai, Assam (26°N and 93° E). Not much is known about this earthquake as it occurred at the height of World War II, when the threat of Japanese aggression on the eastern border of British India was extremely high. There were fissures and great unevenness in what had previously been level ground, trees had fallen and buildings had been damaged. There was some damage to the Manipur road.

2.4.6 The Arunachal Pradesh Earthquake

The earthquake of 29th July, 1947 having a magnitude of 7.7 Ms occurred in Arunachal Pradesh (28.8°N and 93.7°E). This earthquake was felt over large regions of Assam, Bengal (upto Kolkata) and Bihar (upto Purnea). At Jorhat in Assam water overflowed riverbanks. Cracks occurred in the walls of the buildings at Dibrugarh, Jorhat and Tezpur. There was a failure of electricity at Guwahati. This earthquake was also felt at Silchar, Kathmandu, Rajsahi, Krishnagar, Lasha, Cooch Behar, Mymensingh, Dhubri, Rangpur, Tezpur, Srimangal, Bogra, Kalimpong, Comilla, Darjeeling, Guwahati and Purnea.
2.4.7 The Great Assam Earthquake

This “Independence Day” earthquake occurred in 1950 was the 6th largest earthquake of the 20th century. This earthquake is often referred to as the “Assam Earthquake of 1950”. The epicenter was 20.7 kms NW of Tajobum, Arunachal Pradesh (28.5° N and 96.5° E). Though it hit in a mountainous region along India’s international border with China, 1500 people were killed and the drainage of the region was greatly affected. The resultant floods were the cause of most of the fatalities aftermath of this earthquake. The initial shock was followed by thousands of aftershocks, some of which were big enough to be reckoned. It had a magnitude of 8.7Ms and struck a relatively sparsely populated region along the Indo-China border. It was felt throughout north-eastern India and in many parts of eastern India. It was also felt throughout Bangladesh, Bhutan and Myanmar. Damage occurred in the entire region as far as Kolkata. It was felt across a wide area of the subcontinent, over an area totaling 4.5 million square miles. There was widespread devastation in Upper Assam, the Abor Hills and the Mishmi Hills. The region that suffered the most damage to life and property was 15,000 square miles. This included the districts of Jorhat, Lakhimpur, Sibsagar and Dibrugarh in Assam. Dibrugarh and Saikoaghat were among the worst affected areas. Railway communications were disrupted (Fig.2.4 and Fig.2.6) due to damage to tracks and bridges. There were fissures in the earth, from which water and sand was emitted. These are called sand vents (Fig.2.5) and represent liquefaction due to intense ground shaking. Vast areas of land either were elevated or subsided, altering the drainage of the region. There were huge landslides in the mountains and these dammed tributaries of the Brahmaputra River, like the Dihang, Dihing and Subansiri. The latter was dammed by landslides for several days and some worst liquefaction damage was reported from the area where the river enters the plains. These were breached a few days later and resulted in serious flooding. Most of the loss of life was as a result of the flooding and not directly from the earthquake. Alterations of relief were brought about by many rock falls in the Mishmi Hills and destruction of forest areas. 1,526 deaths were recorded, out of which 600 were from Lakhimpur and Sibsagar districts alone. In the Abor Hills 70 villages were destroyed
Fig. 2.4: Bent rails at Tezpur

Fig. 2.5: Sand vent at Rowmari

Fig. 2.6: Bridge on Ranganadi, Assam

(Source:http://aasc.gov.in/course material/Disaster/SCENARIO OF SEISMIC HAZARD IN ASSAM.pdf)
with 156 casualties due to landslides. Dykes blocked the tributaries of the Brahmaputra; that in the Dibang valley broke without causing damage, but that at Subansiri opened after an interval of 8 days and the wave, 7 metres high, submerged several villages and killed 532 persons. The earthquake was followed by a large number of aftershocks, most of which were of magnitude 6.0 or greater. These were very frequent following the earthquake and continued for many years after the main shock. The aftershocks were located primarily in the central portion of the meizoseismal area and extended considerably beyond the limit of the landslides to the north and to the southeast.

2.4.8 The Arunachal Pradesh Earthquake

This shock had a magnitude of 7.7 Ms and had its epicenter in Manipur-Burma border (24.2° N lat. and 95.1° E long.). It occurred on 21st March, 1954. The shock was felt widely over whole of Assam, Bengal and parts of Bihar and Orissa. Minor damages were reported from parts of Assam.

2.4.9 The Arunachal Pradesh Earthquake

This earthquake of 1st July, 1957 had the magnitude of 7.0 Ms it had the epicenter near Indo-Burma border (25° N and 94° E). This earthquake was widely felt over Assam, Manipur, Tripura, East Pakistan and parts of West Bengal and Bihar. Within Assam, the shock was felt at Tezpur, Halflong, Guwahati, Kailasahar, Silchar, North Lakhimpur, Rowriha, Kumbhirgram, Kohima, Dhubri, Lumding, Pasighat, Imphal, Bindukuri, Shillong, Mazbat, Goalpara and Agartala. However, only Silchar (Cachar) reported minor property damage.

2.4.10 The Cachar (Assam) Earthquake

This event occurred on 31st December, 1984 at SSE of Silchar, Assam (24.64°N and 92.89° E) and is of magnitude 6.0 Mw. This earthquake affected an area of about 250 sq km. 20 people were killed in Cachar District and 100 were injured. Damage was of moderate nature except around Sonaimukh Bazar area. The Sonaimukh bridge over the Sonai river and a few school buildings got severely damaged. The Sonaimukh bridge was dislodged from the abutment towards SE direction as a result the bridge was closed to traffic. Two furlongs away from the said bridge, the Nitya Gopal High School and the Sonai Senior Madrassa were severely damaged. These schools were housed in
traditional Assam type buildings having walls made of ikra or bamboo strips being cement plastered. Unfortunately the half brick walls were resting on the floor rather than to the foundation. The wall fell towards north. The entire desk-bench were thrown haphazardly over the floor, the ceiling fans got twisted, heavy almirah also tilted. The boundary walls of both the schools were raged to ground. A few furlongs away two mosques were also affected and one the bell tower was thrown to a distance of about 20 feet. Numerous cracks developed on the floor and walls.

2.4.11 The Tipi (Arunachal) Earthquake

The zone confining to MBF near Tipi experienced an earthquake of magnitude 5.3 Mw on 12th October, 1985 at a depth of 9 km and has its epicenter at Assam-Arunachal boundary. Later, numerous events of magnitudes 3.0 mb-4.5 mb occurred in this zone at depths 10-30 km. Kameng fault is also passing vertically and meeting MBF though this point. This is one of the zones where the Himalayas change trend from E-W to ENE- WSW and gradually assume NE-SW trend. This earthquake caused extensive damage in and around Tipi. The orchid farm at Tipi and its housing colony suffered damage. The earthquake was followed by a large number of aftershocks of moderate strength.

2.4.12 The Manipur-Myanmar Border Earthquake

This earthquake occurred on 6th August, 1988 with its epicenter at Indo-Myanmar border (24.14°N and 95.12°E) and was of magnitude 7.3 Ms. Its hypocentre was at a depth of 91 km. It lasted for two minutes and tremors were felt in the entire Northeastern region, Myanmar, Bangladesh and Nepal. A subsidence of 20 metres was noticed in Guwahati due to this. Four persons died and there was considerable damage to buildings, railway tracts, roads, etc. Jorhat, Silchar and Diphu were the places where maximum damage was recorded. Landslides, fissures, ejection of sand, mud and water occurred in large scale.

2.4.13 Silchar Earthquake

A moderate earthquake struck the Silchar region (24.71°N and 92.53° E) in Assam, India, on 9th December, 2004 at 14:19 PM local time causing a few injuries and
minor damage to property. The earthquake had a magnitude of 5.4 Mw and was felt in many parts of north-east India and Bangladesh.

### 2.4.14 Sikkim Earthquake

An earthquake of magnitude 6.9 mb occurred on 18\textsuperscript{th} September, 2011 which has its epicenter at 27.72\textdegree N latitude and 88.06\textdegree E longitude of magnitude 6.9mb. The earthquake struck near a mountainous, very populous region near the Sikkim–Nepal border. The strong shaking caused significant building collapse and mudslides; at least 111 people were confirmed killed by the effects of the earthquake, and hundreds of others sustained injuries. As the earthquake occurred in the monsoon season, heavy rain and landslides rendered rescue work more difficult. Tremors were felt in other parts of northeast India, Delhi, Kolkata, Lucknow and Jaipur.

### 2.4.15 Nagaon Earthquake

This event occurred on May 11, 2012 and was of magnitude 5.4 mb. The epicenter of this earthquake was at Nagaon, Assam (26.18\textdegree N and 93.03\textdegree E). Some buildings developed cracks after the tremor but no casualties were reported. Tremors were felt in other parts of Northeast India and some mild ones even in Kolkata.

### 2.4.16 Recent events

(i) An earthquake measuring 5.2mb on the Richter scale occurred in this region on 2\textsuperscript{nd} March, 2013. No casualties were reported. The quake was felt around 7.01 a.m. in most parts of the northeast region and neighbouring Bangladesh, and its epicentre lay along the India-Bangladesh border near western Tripura (27.46\textdegree N and 91.19\textdegree E.)

(ii) An earthquake measuring 4.6mb on the Richter scale occurred in this region on 16\textsuperscript{th} April, 2013 at 6:53 a.m. jolting people out of bed. The epicentre of the earthquake was located in Darrang district of Assam at 26.3\textdegree N latitude and 92\textdegree E longitude. There was no report of any casualty or damage to property so far due to the quake which rattled doors and windows.

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