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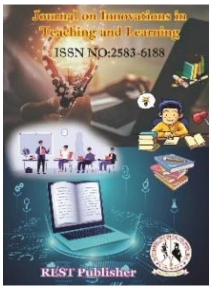

Earthquake History of Assam and Its Geological Record within Some Sedimentary Structures in Upper Assam

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Abstract: *The geology of Assam has played a significant role in the occurrence of notable earthquakes in the region. In a broad regional geological point of view the Assam Arakan basin is within the tectonically active region with the presence of the triple plate junction and there are many records of major earthquakes with a magnitude of above 7 in Richter scale. Major earthquakes in Assam are caused by intense tectonic activity from the collision of the Indian Plate with Eurasian & Burmese plates, creating numerous active faults like the Kopili Fault, Himalayan Frontal Thrust (HFT), and Main Boundary Thrust (MBT), placing the region in the highest seismic zone (Zone V) and making it highly vulnerable. The complex interaction along these fault lines, coupled with the region's geological setting, results in frequent seismic events. Along with a thorough review of available archival records in this study an attempt has been made to explain geologically the earthquake induced structures found within Quaternary deposits of Upper Assam.*

Keywords: *Assam, Earthquake, Geology, Triple plate junction, Seismic zone (Zone V), Earthquake induced structures.*

1. INTRODUCTION

Throughout history of human civilizations it witness to the profound and catastrophic influence of these seismic events, underscoring the entwined relationship between human civilization and the powerful 'forces of nature'. Early human had different explanations about the cause of earthquake and most of these explanations were related to the anger of God. In contemporary society, the study and understanding of earthquakes continue to play an instrumental role in informing disaster mitigation and response strategies. Thomas Oldham, the director of the Geological Survey of India has left a catalog of earthquakes of early India. His son, Richard D. Oldham has also given account of some of the major earthquakes in India. In this present study makes an attempt has been made to explain earthquake induced structures in three sections namely, the Barhapjan Section, the Dum Duma-I section and the Dum Duma Hansara Section have been examined near Dum Duma town of Tinsukia district(Upper Assam).

2. GEOLOGICAL SETTING

In a regional geological point of view the Assam Arakan basin is within the tectonically active region with the presence of the triple plate junction and there are many records of major earthquakes with a magnitude of above 7 in Richter scale. Major earthquakes in Assam are caused by intense tectonic activity from the collision of the Indian Plate with Eurasian & Burmese plates, creating numerous active faults like the Kopili Fault, Himalayan Frontal Thrust (HFT), and Main Boundary Thrust (MBT), placing the region in the highest seismic zone (Zone V) and making it highly vulnerable. The complex interaction along these fault lines, coupled with the region's geological setting,

The locations of the earthquake induced structures are found in three sections namely, the Barhapjan Section, the Dum Duma-I section and the Dum Duma Hansara Sections are near Dum Duma town of Tinsukia district(Upper Assam).

3. REVIEW OF THE SIGNIFICANT EARTHQUAKES OF THE PAST

Assam has experienced some significant earthquakes in its past, causing widespread damage and loss of lives. A major earthquake to have occurred in the region's history was the Cachar Earthquake of 1869. With an estimated magnitude of 7.4 that occurred in the Kopili fault, the earthquake rocked the region causing massive damages in Imphal (present day Manipur) and Silchar besides affecting Guwahati, Nowgong, Lakhimpur, Dibrugarh, Nagaland and Sylhet. It also rocked places in West Bengal and Bihar (Kumar Pallav 2010).[1] One of the most devastating earthquakes in the region's history occurred in 1897, known as the Shillong Earthquake of 1897. This earthquake, estimated to have a magnitude of 8.7, resulted in extensive destruction, primarily affecting the districts of Sylhet, Khasi Hills, undivided Goalpara, Kamrup and Nowgong. Based on the data of North East Institute of Science and Technology (NEIST), Jorhat history of some major earthquakes in this region is given in Table-1.

TABLE 1.

Place	Year	Magnitude
Cachar, Assam	March 21,1869	7.8
Shillong, Meghalaya	June 12, 1897	8.7
Sibsagar, Assam	August 31, 1906	7.0
SW Assam	Sept, 9, 1923	7.1
Nagaland	1932	7.0
Arunachal(NEFA)	July 7, 1947	7.5
Upper Assam	August 15, 1950	8.7
Patkai Range,Arunachal	1950	7.0
Manipur-Burma Border	1954	7.4
Kumbi, Manipur	1957	7.3
Darjeeling	1957	7.5
Indo-Myanmar Border	August 6, 1988	7.5

Major earthquakes always left significant geological deformation, leading to the modifications of landforms, uplifts, and subsidence. Earthquakes events of the past in Assam had left some geological impact which was found in archival records.

3.1 Impact on River Dynamics

Major earthquake like the earthquake of 1897 has influenced the hydrological dynamics of Assam's rivers, with direct consequences for the region's geological features. Seismic events triggered changes in river courses, leading to avulsions, raising of river beds and the reconfiguration of fluvial landforms, shaping the courses and characteristics of the region's waterways. Detailed inspections after the Earthquake of 1897 revealed that the Brahmaputra River and its channels had become shallower following the earthquake. Following the earthquake, the river bed had been raised by more than a foot in some areas and sand bars were formed lower down which kept the level of water higher than usual. In parts of the Kamrup district, the earthquake was immediately followed by a sudden rise of water from the rivers and beels which had been partly filled up with sand by the earthquake. The damage done by the floods which followed the earthquake was much greater than that caused directly by the earthquake. The numerous rivers which fall into the Brahmaputra also rose in flood at the same time. Pandit Matadin Sukul's inspection shows (Report by Pandit Matadin Sukul 1897)[2] that between Sontoli in Kamrup and a little below Hatimura, Nowgong, the river was broken into two channels, which again joined lower down. There was hardly 5 feet of water in either. Following the earthquake commanders of cargo steamers viz. 'Shillong Down' and 'Varuna Down' found shallow waters in the channel leading out into the main stream above Mangaldai. Cargo steamer 'Dilwara' also found shallow water while sailing between Tezpur and Guwahati on 1st December, 1897.

In the town of Goalpara, the land lying close to the bank slid forward towards the rivers, creating series of cracks running parallel to the bank, the upper most cracks extended up to the slope of the Goalpara Hill. A portion of the hill had also slipped in during the earthquake of 1897. In Dhubri town, following subsequent floods, the river shifted its channel to almost the middle of its bed and formed a big char opposite to the town. Steamers coming to Dhubri from Goalpara town found the channel getting shallower. In West Guwahati, much sand was thrown up in the Brahmaputra during the earthquake and the banks slipped in with trees, obstructing channels. The Khanajan bridge with masonry abutments and piers had also collapsed which almost blocked the channel. Back waters were thus set in, and crops higher up were damaged by the spill waters of the river.[3]

During the earthquake, the Kalbhog channel was entirely blocked from the place of its bifurcation to near Salisala Village in Chayani mauza, Kamrup. The length of the closed portion was about 4 miles. The bed turned dry and almost leveled with the bank. This channel was previously used for irrigation and drinking purpose in Rani and Chayani mauzas, Kamrup. In Barpeta, the bed of the Hirajan and the Marachaolkhoa rivers were raised by 7 feet while the Saru Manas was raised by 3 feet following the earthquake. The strand road in front of the courthouse and other government buildings had sunken from 3 to 5 and a half feet. The examination of the interior of the Barpeta town showed that many of the low places were filled in with sand geysers and silt deposit, and the artificial grounds or mounds on which the houses were built had sunk along with the embanked roads. Owing to the sinkage of river banks and raising of their beds, subsequent floods followed which caused much damage to the town. The rivers which caused most floods in the Barpeta subdivision were Noanadi, Pagladia, Tihu, Caldia, Pohumara and Saru Manas. During the earthquake landslips occurred in the Bhutan Hills and sand geysers were formed in a number of places. The subsequent rains brought down loose soil from the hills and distributed it all over the town. Beels were also silted up and their beds raised. At the Trunk road crossing, the Pagladia river got dried up by sand springs during the earthquake and remained so for a day, when waters from the hills rushed in and scoured its bed. Two of its tributaries, viz. Alpa and the Singra were silted up and ran in different channels.

In Goalpara, during the earthquake, bars of sand were formed at places and the channel of the Manas river became very shallow. The sliding of banks into the river bed was also observed in many places. Some of the other rivers of the South bank which were affected during the earthquake were Deosila, Bherbheria, Dudhnai, Krishnai, Jinari, Gara, Jinjiram and Kalu.

During the earthquake, the banks sank and slipped into the bed and blocked the channel at many places, with the result that the subsequent floods overtopped the banks and caused considerable damage to crops. Apart from voyage, these channels were regularly used for timber floating from various neighboring hills which was halted after the blockage owing to the earthquake. The Krishnai River, one of the largest rivers of Goalpara subdivision was blocked at various channels. Backwaters were formed which caused great damage by submerging extensive tracts. Sali paddy and a large portion of the sal forest lying West of Jiar rora was submerged whereby around 50,000 sal trees were destroyed. The back waters also caused damage to the Trunk road near Krishnai by washing away three bridges and widening their openings. Foothills were flooded as well.

The forcing up of the river beds was not uniform, and in some places was more extensive than in others. This led to the formation of barriers across the stream, and on the upstream side the water was ponded up to the height of the maximum rise of the next barrier downstream.

3.2 Earthquake induced Landslides and Erosion:

Major earthquakes have heightened the susceptibility of the region to geological hazards such as landslides, slope instability, and erosion. Seismic events triggered mass movements leading to the reconfiguration of hill slopes and sediment transport, thereby influencing erosion patterns and geomorphological evolution of the landscape. The Cachar Earthquake of 1869 caused big landslips in the Naga Hills of colonial Assam. An extract from the Deputy Commissioner of Naga Hills' diary(Report of the officiating Deputy Commissioner, Naga Hills, 1869, Assam State Archives)[4] showing an account of the earthquake as experienced by him at the village of Keromah, Naga Hills goes as :

As the first great wave passed, I noticed on my right a great cloud of dust go up from a landslip under the village of Biffomah to the north of me, and almost directly afterwards another rose from a low hill to the south-west of Biffomah, followed directly by a third from a huge landslip under Geroophemah, which also bears south-west from Biffomah… Directly the shock was over I found that the earth had opened in several places, the fissures were of considerable length and sufficiently wide to admit of the insertion of two fingers abreast, one of the graves at the edge of the khud had cracked right across, the end of another had been shaken down… on my return to Samoogoodting I noticed on the road that the rivers were discolored and swollen… that there had been a fresh fall of rocks and earth from old landslips, and that new landslips had occurred in places.

Regarding landslips in Bhutan Hills surrounding Assam due to the earthquake of 1897, the Sub-divisional Officer of Mangaldai wrote: The principal damage has been done in the outlying ranges of the Bhutan Hills. Many roads have been carried away by the landslips caused by the earthquake, but very little loss of life was incurred(Letter from Lieutenant Colonel M.A. Gray).[5]

3.3 Earthquake induced Earth Fissures, Sand Vents and Allied Phenomena:

During major earthquakes in colonial Assam, seismic events triggered the formation of earth fissures and sand vents due to intense ground shaking, liquefaction, and the release of pore water and sediments. The geological impact of these earthquakes led to the development of distinctive surface features, providing evidence of the seismic disturbances and their effects on the landscape.

Seismic forces acting on the ground during major earthquakes in colonial Assam led to the development of earth fissures, also known as ground ruptures or earthquake ruptures. These fissures were manifested as fractures or cracks in the earth's surface, resulting from horizontal and vertical displacement of the ground along tectonic fault lines. Fissures in the ground, the formation of vents from which sand, water and mud pouring out have been numerous and widespread during the earthquake of 1897. The pushing forward of the abutments of the bridges was universal throughout the fissured tracts and the narrowing of the river channels seems to have been still more conspicuous in places where there were no massively built bridges to assist in supporting the banks. In all cases of earthquakes it was due to the throwing off of the unsupported river banks and accompanied by the formation of fissures (Report of Richard Dixon Oldham).[6]

Another very striking result of the displacement of the alluvium, whether by throwing off at the free surfaces of river channels or tanks or otherwise, was the bending of rails. There are a series of photographs showing the effects of the earthquake on the Assam Bengal and Eastern Bengal Railways and on the Tezpore Balipara tramway.[7] The lateral and vertical movement of the ground during the seismic event caused the rail tracks to contort and deform, disrupting the alignment and structural integrity of the railway lines.

At Nowgong, the ejection of sand had such force that covers of wells, imbedded in mortar were hurled aside. The other was at Goalpara where a well was altogether filled with sand and a portion of the wooden cover was hurled 30 feet distant where it lay half buried.[8]

4. FIELD STUDY: EARTHQUAKE INDUCED DEFORMATIONAL STRUCTURES

During this study some deformational structures were observed in Dum Duma area of Tinsukia District of Upper Assam within the Quaternary deposits. The criteria for correlating deformation structures with seismic events as given by Sims (1975)[9] have been considered as established rules for this present study.

The Quaternary deposits occurring within southern part of the Brahmaputra valley are classified on the basis of morphology, lithology, and height. GSI (1978)[10] mapped three morphostratigraphic surfaces as geological formations, viz. Dum Duma Formation, Dangori Formation and Saikhoa Formation in this part of the Brahmaputra basin.

Soft sediment deformational structures formed during sedimentation or before compaction and cementation of sedimentary strata have been used in sedimentology for characterizing depositional episodes, paleocurrents and paleoslopes. Thses structures generally occur in coarse silt to fine sand size range sediments but occasionally silt clays also exhibit these structures. The formation of these structures is inherently related to grain cohesion, permeability and rate of deposition of the sediments which are the dominant factors in soil mechanics. Vertical displaceing forces like liquefaction, reverse density gradation and slope failure along with horizontal deformational factor like shear stress represent the dominant mechanisms for their formation (Blatt et all., 1980)[11]. Earthquake induced deformational structures are called 'Seismites',they are considered as sedimentary evidences of past seismic activity (Sims1973, 1975, Mills, 1982; Mohindra and Thakur 1998; Chaudhuri, 2007a, 2007b)[12].

In the year 1975 after doing a very good study on deformational structures in young sediments J.D.Sims suggested the criteria for correlating deformational structures with seismic events as follows:

i) the deformational features occur in seismically active region,
ii) these are restricted to single stratigraphic layers separated by undeformed beds over a large area,
iii) the beds are near horizontal so as to exclude the possibility of slope failure as a potent trigger mechanism in their formation,
iv) presence of potentially liquefiable sediments.
v) the structures are similar to those described by Sims(1973)[13] or formed experimentally by Keunen(1958)[14].

Description of the Deformational Structures

The Borhapjan Section is 750 cm high from water level in winter season. It is a natural river cut scarp which separates T_2 and T_3 Terrace level in that area and it is shown in Fig.1(A). The deformation structures present in this section show that they are characterized by mainly folds with sharp, irregular crests and broad, round troughs of convolute folding. [Fig.1(B),1(C).]

The Dum Duma-I Section is 640 cm high from water level in winter season.The deformation structures present in this section are characterized by convolute folding, small scale faults, anticlines, sand dykes and flame structures. [Fig.1(D)

The Dum Duma Hansara Section is 530 cm high. It consists of 3 units where the topmost unit is about 155cm brown massive clay. It is underlain by poorly laminated yellowish clayey fine sand of 235cm. The underlying third unit is 140 cm thick and composed of white fine to medium sand with some deformation features. The deformation structures present in this section are mainly convolute folding and flame structures.[Fig.1(F)].

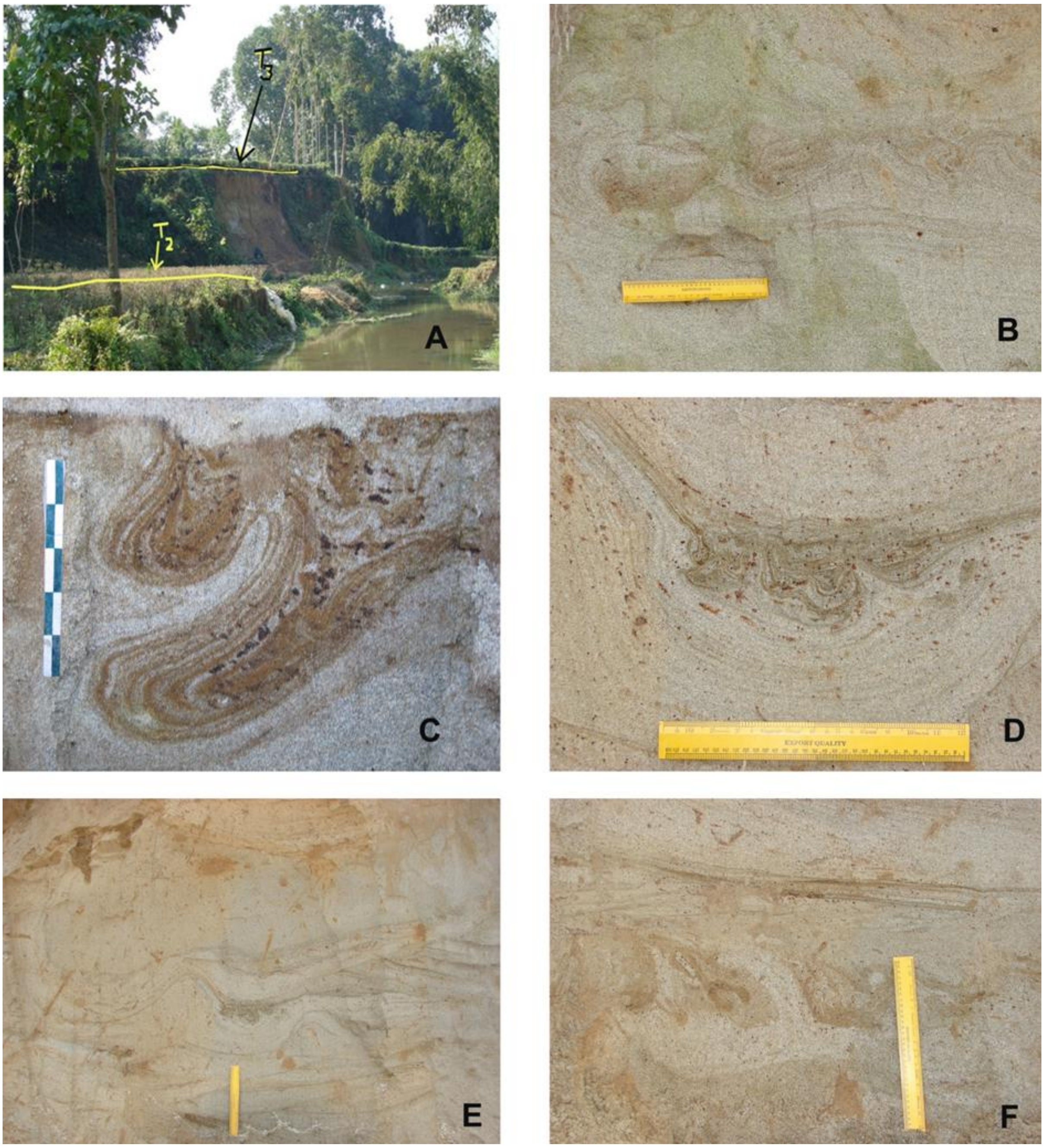

FIGURE 1. Field photographs (A, B,C,D &E)

Discussion:

The geological setting of the study area indicates that it is situated in a tectonically active region in both regional geological as well as local geological scale of observation.

The deformation structures have well developed in the Quaternary alluvial sediments mainly in middle part of the Dum Duma Formation.

Field observation of the Borhapjan section shows that the deformation structures are overlain by brownish silt to very fine grained sand with (indistinct) discontinuous horizontal laminations of 215cm thick. Similarly the deformation structures in the Dum Duma Hansara Section are overlain by a poorly laminated yellowish clayey fine sand of 235cm. Again in the Dum Duma Hansara Section the deformation structures are overlain by poorly laminated yellowish clayey fine sand of 235cm.

In this study the main structures are characterized by convolute folding, small scale faults, anticlines, sand dykes and flame structures. These structures are widespread in the region and are bounded by nearly horizontal Quaternary undeformed layers/beds and these structures are similar to those described by Sims (1973).

Thus based on our observation made on (1) tectonic setting of the sub-basin; (2) the sedimentary environment and sedimentological characteristics of the successions in which the deformed layers occur; (3) their lateral extent; (4) their recurrence at different stratigraphic levels; and (5) their similarity to those described as seismically induced deformation structures in other areas, we interpret these features as having developed as a result of increased pore pressure and vertical or horizontal stresses induced by seismic activity.

Therefore the deformation structures observed in the Dum Duma area are interpreted as seismites, developed as a result of the major earthquake impact.

5. CONCLUSIONS

The deformation structures observed in the Dum Duma area are interpreted as seismites, developed as a result of the major earthquake impact.

The study has shown us how the seismic events of the past have left an indelible mark on the geological features of Assam including reshaping its topography and landforms.

The study helps us to understand the geological cause behind the shifting of river channels and upliftment of river beds which are again related to the flood and erosion problem of the region.

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