Chapter- IV

Palaeoseismological features and identification of events

4.1 Introduction

Palaeoseismological approaches are being increasingly used throughout the world to understand the behavior of active faults. These methods have proved it's effectiveness in documenting the prehistoric earthquakes based on the analysis of seismically induced structures from the geological sequences and their interrelationship in a geochorological framework. Basically, the study provides answers when and how often palaeo-earthquakes occurred. Extrapolation of this information from instrumental and historical records is not possible. From a systemically conducted study in an ideal site, a broad spectrum of geological data can be retrieved on slip rate, recurred interval, elapsed number of events and faults geometry. These data can be used to develop long term earthquakes potential and hazard models. Apart from the standpoint of seismic hazard evolution, these studies help us to understand the regional deformation along major faults and crustal evolution in general.

A sub-discipline within broader fields of neotectonics and active tectonics, palaeoseismological studies require a multidisciplinary approach using techniques followed is seismology, structural geology, tectonics, Quaternary geology and even archeology. Over and above, accurate dates of event horizons and seismically induced features are the basic
data on which palaeoseismic interpretations can be built on. An integrated geological approach towards active faults requires elements of remote sensing, air photo interpretation and geological field mapping and geophysical survey. Excavation of fault zone to identify fault related structures should be the final step, after identifying suitable sites based on above data.

Although significant contributions have been made on the earthquake process, palaeoseismologic studies have to deal with glaring uncertainties. These problems start primarily from the nature of geological sequences itself. Generation and preservation of the seismically induced structures depend upon fortuitous combinations of geological conditions, somewhat analogous to fossil preservation. Secondly, the uncertainties in age dating have serious implications on deducing realistic chronological controls. As in any branch of science, a rigorous methodology has to be followed in the palaeoseismic investigations too Multiple lines of evidence should be checked and rechecked before results are finalized. The only way to overcome the limitations is to increase the quality and range of database of the historical earthquakes so that we have a good set of calibrated events. This requires time consumption and co-ordinated efforts for years to come.

India offers a variety of seismotectonic provinces where palaeoseismologic studies can be pursed. It may also be necessary to
develop site specific technique to unravel seismic history of a given region, and of course, strive for quality in data collection and interpretation. This is a nascent field where new advances are possible. The ultimate aim should be to document the long-term behavior (e.g. recurrence interval and slip rate) of all the active faults in the country, so that we have a better estimate of seismic risk in those areas. Eventually a co-ordinated strategy has to be evolved, so that we are able:

1. To develop and apply techniques to characterize rates of deformation and earthquake recurrence interval even in places where surface faulting is poorly expressed.

2. To improve and develop new methods for dating late Quaternary deposits and surfaces that can be used to date the event horizons and quantify rates of deformation.

3. To develop and integrate geological, geodetic and geophysical data to characterize potential earthquake sources and fault segments.

The northeastern part of India is seismically active and witnesses several major earthquakes during the historical records. It is quite convincing to belief that beyond historical time there occurred several major earthquakes in the region during the Quaternary period. Identification and
estimation of magnitudes of those palaeo-earthquakes is going to enhance our earthquake database, which in turn will help us in interpreting the seismo-tectonics of the region in much better way. In this context, the present research work on palaeoseismology of the Shillong Plateau in the area of mesoseizmal zone of 1897 earthquake has been taken into consideration and utmost care have been undertaken in sites selected which are identified as suitable location of palaeo-liquefaction.

4.2 Palaeoseismic signature of the selected study site in an around Shillong plateau

Site selection for palaeoseismic study was done on the basis of following criteria.

- Base map Study
- Satellite imagery
- Previous Literature
- Archeological Evidence
- Geological features
- Local information

4.2.1 Site name: Chandubi (Ukim)

Location: (91° 25' 26''E: 25° 52' 35''N) (Fig 2.2 Chapter-II)

Background: Chandubi lake was first taken into consideration as palaeoseismic site for this Phd research work. It is around 65 Km from
Guwahati city, Assam. The lake is at the base of Garo hills bordering Assam and Meghalaya. The place is surrounded by deep forest, tea garden and small and discrete villages. This place is home for migratory birds, wild animals, raw jungle, undulating tea garden also present along with a fast flowing mountain river and the serene lake.

There is a famous tale in Assam that this lake was created due to subsidence of ground in 1897 great Assam earthquake. Local village level survey was conducted to understand the real story that has been accepted by the last generation to the present generation that reside in and around the famous Earthquake lake (Chandubi) It is an accepted fact for the local residing people of the area to believe that the lake is formed due to ground subsidence during great Assam earthquake of 1897.

**Tectonic Setting:** The Lake is situated in a tectonic environment in the domain of the NNE-SSW trending Kulsi Fault and where the fault cut across the ENE-WSW linear fabric. The early Survey of India toposheet of the area shows that the lake environment prevailed along both sides of the Kulsi River (representing the “active” Kulsi Fault. The epicenter of 1897 earthquake falls in the north west direction with respect to Chandubi (Fig 4.1)
Fig: 4.1 Seismotectonic map interpreted of Chandubi from the Landsat-7 ETM+ image. Image source: GLCF website. Seismic data source: ISC.

**Palaeoseismic induced geomorphic signature of Chandubi Lake**

Study carried out based on the available literature, toposheet and satellite imageries to understand the tectonic and palaeoseismic signature of the terrain. Chandubi lake (beel) is located in the northern foothills of the Shillong Plateau (Fig 4.2) The early Survey of India toposheet of the area shows that the lake environment prevailed along both sides of the Kulsi river (representing the "active" Kulsi Fault) during 1911-13 (Fig.4.3). The western dominant lake is called Ukiam Lake and the eastern prominent lake is known as the Chandubi Lake. Subsequently, the western lakes transformed into alluvial plains and the size of the Chandubi Lake has been reduced as documented in the toposheet of 1967-68 survey Duarah.
et.al (2007) (Fig.4.4). The Landsat-7 ETM+ image of the year 2002 shows further reduction in size of the Chandubi Lake.

The water body located in the westernmost part is the Ukiam beel having an area of about 311 Ha had completely transformed into alluvial plains as recorded in the Survey of India toposheet of 1967-68 survey. (Fig.4.4). The Chandubi beel had an area of about 1023 Ha in the year 1911 which reduced to 225 Ha by the year 1967. During the period about 194 Ha of water body has been transformed into marshy land. Thus, the Chandubi had diminished its effective size by 604 Ha (i.e. more than 59% of the original size in 1911) within a time span of 56 years in a relatively stable plateau, where geomorphological processes are generally less active than the near by Himalayan belt in the north of the Brahmaputra valley. At present, the lake further gets its size reduced by siltation process as well as through active eutrophication. But certainly, eutrophication process cannot be held responsible for such anomalous reduction of size of the Chandubi Lake as evidenced by sediment profiles along the lake margins. The Chandubi Lake has been further reduced in its size in course of time and its area, as depicted in 2002 ETM+ image, is only 119 Ha of water body remains (Fig.4.5) which is less than 12% size of 1911 and almost in the verge of vanishing out. A north flowing palaeo river system located north-northeast end of the Chandubi beel may indicate a possible outlet of the lake through the river system (Fig.4.3). Which is the general slope direction of the topography.
There are numerous upright tree trunks Fig 4.6 located in the north-eastern part of the lake. In the north, the sediment profiles, in most of the subsided areas, are thin and mainly composed of clay-sized sediments. Load structures in the sediments are very common in the southern part of the lake.

Undoubtedly, such huge sedimentation in the lake might result due to rock and landslides that took place in the interior parts of the Plateau within the catchment area of the Kulsi River. These above activities are evidences of palaeo tectonic volatility in that area.
Fig. 4.2: Geological map of the Shillong plateau interpreted from the Landsat-7 ETM+ image. Image source: GLCF website.
Fig. 4.3: The map of the Chandubi area prepared from the Survey of India toposheet of 1911-13 (one inch to a mile). Inset is the location map of the area.

Fig. 4.4: Status of the Chandubi Lake during 1967-68 as depicted in the Survey of India toposheet on 1:50,000 scale.

Fig. 4.5: Status of Chandubi Lake in the year 2002 as interpreted from the Landsat-7 ETM+ image. Image source: GLCF website.
Trenching: Trenching was done in various places around Chandubi Lake and its nearby surrounding water body Fig 4.7 in search of palaeoliquifaction structure and possible signature of seismotectonics feature. However, no convincing seismites (Palaeoliquefaction structures) have been recorded from any part of the lake. Although few dyke like structure Fig 4.8 has been trenched out, but as the water table in the lake area was high so it was not possible to trench down further which lead to fragmentary study and it cannot be inferred that mother source bed do exist to support the dyke. During investigation on palaeoseismic features through trenching in the surroundings of the lake highly deformed structures have been observed, along with soft sediment deformation, Fig 4.9 viz., load structures are abundant in the upper part of the profiles. Fig 4.10 No seismic deformation features, sand dyke etc. are observed in the position of the Ukiam Lake too. If some structures had developed in those areas, the river dynamism might have wiped out such features. It is also possible that we might have missed the hidden palaeoseismic liquefaction strictures if any during our field study.

However sediments unit of about 25 cm thick penetrated (palaeoliquefaction Sill) within the gneissic regolith about 2.75 m below the present ground is found Fig 4.11 sample is collect for laboratory study, The silty sand layer dated in the lab. Thermolumenescence dating techniques in quartz grains has been applied which is described in details in (chapter V)
Identification of Events horizon: There is no such distinct palaeoseismic events detected in the strata of the Chandubi and its adjacent lake area, the samples collected from lake area and sand layer in gneissic regolith can reveal the palaeoseismic event after dating of samples age.
Fig 4.6 (above and below) Tree trunk in the chandubi lake
Fig 4.7 (Above and Below) Tranch site in Chandubi and its adjutant area
Fig 4.8 (Above and Below)(Bench mark pen 13cm) Sand dyke like structure found in Chandubi but due to water table near surface, it was not possible to trench down, as a result mother source sand bed cannot be excavated, so it cannot be concluded as seismothectonic evidence.
Fig 4.9 (Bench mark fire box 6 cm) Highly Deformed Sand layers in between horizontal Clay layers

Fig 4.10 (Bench mark fire box 6 cm) two load structures excavated in Chandubi. Clay layers are truncated by sand load.
4.2.2 Site name: Chidrang Fault

Location: (90°38'20"E; 25°54'04"N) (Fig 2.2 Chapter– II)

Background: Chidrang Fault area comes under Garo hills named Dilma. The place is famous for reserve forest with mist of wild animal of different species, it is also vulnerable to natural calamities like cyclone, earthquake etc. Chidrang fault was formed during 1897 earthquake which fallowed the Chidrang River, it is one of the world recognized earthquake which have caused such a large rapture (Oldham 1899). During the 1897 event a section of 6 km length of the Krishnai river course between Jeera and Beltaghat was abruptly changed to its present course

Tectonic Setting: Chidrang fault is situated in the western part of the shillong plateau Oldham (1899) stated that the north bank of the Chidrang
River Fig 4.12 rises by about 18 feet due to the Great Assam Earthquake of 1897. Since then, many low to moderate magnitude earthquakes have been reported in the area which evidenced for active nature of the N-S trending Dudhnoi and Kulsi faults. During the 1897 event a section of 6 km length of the Krishnai river changed its course towards the west due to uplift of the area east of the river and at many places ejection of liquefaction sand and water was reported (Oldham 1899)

**Trenching:** For the present study only one suitable section Fig 4.13 was found through attempts in some more sections have been undertaken. However, no significant results have been from this section also the successful trench section has been described below. The seismite section Fig 4.14 under the present study is of 10m in length and 2.5m in breadth. The section is oriented along $80^\circ-260^\circ$. (East-West)
Fig 4.13 (Benchmark is Pen of 13cm) Chidrang Fault Multiple sand dyke intrusion and sand blows (flame-like) are found. Three palaeoseismic sand dykes 1, 3 and 4 are visible, 2 is the detach part of sand dyke 1 as evidence from field observation. To develop liquefaction features by earthquake should have magnitude higher than 6 (Scott and Price 1988) So all these features probably resulted by earthquake of $M>6$. 
Fig 4.14 Chidrang Fault Multiple sand dyke intrusion 1,3 and 4. Sand blows (flame-like) are found. Based on dyke three palaeoseismic event are visible which either represent multiple palaeoseismic events horizon or could have formed in single event by multiple sand layers present in the area as source.

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C.S- Coarse sand
F.S.- Fine sand
R.S- Ripple sand
Fe- Iron
(1) – Chidrang - 1 sample
(2) – Chidrang - 2 sample
(3) – Chidrang - 3 sample
(4) – Chidrang - 4 sample

Identification of Events horizon: There are three event identified in the section of Chidrang. However it could also be possible that multiple dykes were produced in same event simultaneously. Fig 4.14 and Fig 4.13
The coarser part of the dyke is found at the top with one of its detached part towards the extreme upper tip of the finger dyke materials. An internal structure has not been noticed in the unit and is a massive body. Its colour is brown. The fine unit is found below this coarse unit and resulted due to subsequent reactivation of the earlier dyke vents in a later earthquake. The unit looks like a fire precisely to speak a gently brown candle lamp. It has beautifully preserved interval structures of curved fine lamina. The colour of this unit is grey.

4.2.3 Site name: Kukurmara

Location: (91°25' E 26°03'N ) (Fig 2.2 Chapter- II)

Background: Kukurmara villages come under Kamrup district of Assam. It has construction sand mining from Kukurmara/Kulsi river. It is also famous for old Sal timber market, Kulsi River in Kukurmar area is also the highest habitat of endangered River Dolphins. This area of the Kulsi River is now a tourist attraction for dolphin observation. The local villager reports that the Kukurmara villages have suffer from mass destruction during past earthquakes

Tectonic Setting: The Kukurmara village falls in the periphery of N-S trending Kulsi Fault in the northern part of Shillong Plateau and southern margin of E-W trending Brahmaputra lineament. The area has both active Kulsi river system control by local tectonic of the region and abandoned palaeochannels section of the Kulsi River, which has much older alluvial
plains, this kind of conditions are favorable for preservation of tectonic influenced palaeoliquefaction structures that is sand dyke/ seismite etc.

**Trenching:** Attempts were made to discover palaeoliquefaction structures in this area, after few unsuccessful trenched, in one trenched area clear evidences of seismotectonic deformational as well as palaeoliquefaction structures present Fig 4.15. A detail log was prepared on one of the trenched site and samples are collect for TL dating Fig.16, there are multiple layers of clay and sand are found which has highly affected by the earthquake. There are various size and shape of sand dykes are found ejected from both single fig 4.17 and multiple sand layers, palaeoliquefaction Sill are also common in this area. It is observed that sand dykes have fallowed fracture zone which has behave as the weakest path for liquefied sand to blow out fig 4.17. In trench site fractures are well preserved, on investigation it is found that the liquefied brown colour course grain sand has penetration for more than a feet horizontally and trunked clay layers which can be well seen in the field photographs . The overburden clay layer is thick with respect to alternate bands of sand and clay where from sand has ejected and also deformed this thin clay layers are deformed by ejected sand and deposited on the top of it horizontally producing pseudo sand bed which is actually a liquefaction sills following trend of horizontal bed.fig 4.18 On investigation it is observed that this liquefied sand sill are well connect by sand dykes and multiple dykes on
the other hand are standing on mother sand layers source layers respectively fig 4.19

Further north towards the Brahmaputra (except few minor features), the sediments are largely undisturbed. Similar is the case towards south of the area in and around Kulsi village. These areas have shallow bedrocks and covered by clayey red soils of the hills and are not suitable for generating seismically induced liquefaction features.

**Identification of Events horizon:** In Kukurmara single palaeoseismic event horizon has been discovered in the possible trench site unlike multiple dykes of Chidrang fault (Fig 4.7). There is no multiple generation dyke cross cutting each other are advocated like Chidrang site mention above, but interestingly it has well preserved series of sand dykes and Sill visible from single sand layer, multiple Dykes from multiple sand layers are also present fig 4.19 From field observation it is clear that sand sill are distributed to large area in a form of thin layers and are well connected to dykes. In few cases sand dykes have broken the clay layers under influence of ground shaking and deposit sand on the top of it and is well preserved fig 4.20. Although multiple even is not discovered in the field study of Kukurmara section but it cannot be nullified that the area was not suffered from multiple mega earthquake, the TL dating will help us to understand the relative event sequence if any;
(Fig. 4.15 Trenching is in progress at Kukurmara palaeochannel site. In the background deformation sand and alternate clay layers are visible along with small sand dyke.)
Fig. 4.16 above respectively represent the Kukumara section of trench site. There is an alternation of sand and clay layers covered by soil from top around 90 cm. From the below B it is seen that the clay layers in this expose section is undisturbed whereas above two clay layers D and F lost its uniformity and are deformed due to seismotectonic activity. From the second C and third sand layer E from below it is seen that sand (palaeo-liquefaction) has ejected up to top sand layers G cutting clay bands, and is well preserved in this section. In the mouth of sand dyke on the left side below soil cover sill like structure is seen but due to mixing of soil and surface water it is not possible to confirm the sill criteria.
Fig 4.17 (Bench mark Indian coin 2.5 cm) Two sand dykes are seen in this trenched site which are ejected from single sand host mother source layer. These dykes have followed the fractures available or created by ground acceleration by strong earthquake. Dykes are almost 90 degree and 45 degree stand still in the thick clay layer under soil and vegetation profile, the source mother sand layer is highly deformed by the strong earthquake. The clay layers in between sand layers are affected and the clay beds are distorted by high energy ground shaking and sand liquefaction process. There are thin lamina flow like structure present in the sand beds on the right below side of this photo which indicate the possible flow direction of the liquefied sand. The thin sand layer on the top of the section below soil is stable and no signature of deformation is seen indicating deposition after the event(s).
Fig 4.17 cont. (Bench mark Indian coin 2.5 cm) (above and below) Same trenched section as 4.10 but with wide angle view and below close zoom view of profile and dyke respectively
Fig 4.18 (Bench mark Indian coin 2.5 cm) this section shows deformed alternate bands of clay and sand. There is a prominent dyke exposed cross cutting clay and deformed sand layers and at the top below soil profile there is a thin layer of clay which has preserve palaeoliquefaction sand Sill disseminate few feet horizontally like sand bed. In this section sand blow took place from inside this exposed section and their thickness of dyke varies irregularly with length and depth. The exposed deformed section and palaeoliquefaction deposits shows that the area was subjected to high ground acceleration.
Fig 4.19 (Bench mark Indian coin 2.5 cm) In this section multiple sand dykes are present. Dyke -1 and Dyke-2 both are attached with mother source bed which is responsible for the supply of sand during palaeoliquefaction event Dyke-2 is well connect with Sill. Entire section has highly affected from palaeoseismic effect, clay layers are disturbed and loses its originality and continuation but it only because of clay layers such a dykes are well preserved. Inspite of high defamation the both the dykes are in original position which indicate the single palaeoseismic event, Had there been multiple events, the Dyke-1 would have suffered deformations.

Fig 4.19 cont. (Bench mark Indian coin 2.5 cm) wide angle view of section, Sill and multiple dykes from multiple sand layers but are undisturbed and well preserved though entire section is highly deformed, supporting single palaeoseismic event.
Fig 4.20 (Bench mark Indian coin 2.5 cm) Section shows well preserved sand dyke and its mother source bed. Dyke has cut the clay layers and deposited sand on top sequence. The mother layers has well preserved lamination of sand advocating liquefaction flow where as the top palaeoseismic deposit is unsorted and discrete indicating sudden fresh deposits /dumping of sand.
4.2.4 Site name: Madankamdev Ruins

Location: (91°44'29.9787"E 26°19'10.038"N) (Fig 2.2 Chapter- II)

Background: Madan Kamdev temple is known as the Khajuraho of Assam almost 35 k.m away from Guwahati. The 10th-12th century in Pal dynasty partly ruined sculpture Madan Kamdev temple near river madankuri is an enigma, a mystery, Sculpture scattered all around the Dewangiri hillock, people believes that it was destroyed by foreign invader, some school of thought that it was destroyed in 1897 earthquake. Temple is shrine dedicated to Lord Kamdev (God of Love in Hindu mythology). Nagara architecture had been used in the well- Erotic images sculptured temple having images carved out of monolithic rock.

Tectonic Setting: The historically famous Madan kamdev ruins is situated in the northern part of shillong plateau which is surrounded by the complex tectonics setting, In its north is Brahmuptra lineament , in west is covered by the Kulshi fault and eastern part is bounded by Kopili lineament. The Madan kamdev area comes under Mesothermal Zone of 1897 earthquake

Trenching: A site near natural levee of palaeochannel named madankuri near Madan Kamdev temple was select for trenching, few unsuccessful trench were encountered and in some cases sand dyke like structure is seen, On further down hole investigation it is not possible to establish the relation with the mother source bed, so it was assumed that it could be
animal activities that might have created the burrows and flowing water during flood might have filled them up with sand. Moreover in few cases it was not possible to trench down as water percolate in the trench site. In the study area two palaeoseismic sections were discovered. Blackish silty sand has ejected from host bed and trapped in the clay layers, Fig 4.21 as the dyke was delicate and thin so sample cannot be collected for laboratory study

**Identification of Events horizon:** Sand dyke of about 3 cm width and 30 cm length have been encountered. Fig 4.22 this palaeoliquefaction structure represent only single even horizon, there is no multiple liquefaction structure is seen or fracture detected, Deformation of layers are not prominent as the trenched section exposed above ground water table level part is of sticky clay in nature. The dykes almost of 3 cm width has been maintained all through out the section this because it was probably a animal activity like crab hole which has behaved as weakest path for liquefied sand to eject during palaeoseismic ground acceleration from below mother source bed.
Fig 10.21 (Bench mark a pen 12 cm) Blackish silty sand dyke preserved in sticky clay bed.

Fig 4.22 Field Photo shows black colour sand dyke. The dyke has almost maintain same thickness of 3cm in the profile, it can be assumed that it was a crab hole originally, which might had behave as a weakest zone in the section supporting palaeoliquifaction sand to eject via that 3cm path from source bed down below during palaeoearthquake event.
4.2.5 Site name: Jagi

Location: (91°27'E :26° 02' 30"N) (Fig 2.2 Chapter-II)

Background: study area Jagi site has archeological importance for human settlement, it is believe from local source that there was ancient village of clay workers of different clay type like Heramati clay and Khumarmati clay for pottery making.

Tectonic Setting: The Jagi village like Kukurmara villages falls in the periphery of almost N-S Kulsi lineament in the northern part of Shillong Plateau and southern margin of E-W Brahmaputra lineament. This site is located 25 Km north of 1897 Earthquake lake Chandubi along the fast flowing Bank of Batha river Assam and Meghalaya

Trenching: In present study of palaeoseismology, it has covered not only the geological phenomenon of seismic event but also the ancient archaeological signature section was trenched out in search of any seismotectonic signature if any, Along with the soil profile broken pottery layer extending for few tens of meters are found about 4 m below the ground. Fig 4.23 To understand the phenomenon of such environment whether this could be the result of devastation of any human habitation due to earthquakes on the past so we have collected samples of pottery for TL dating who’s result is discussed in Chapter V.
Identification of Events horizon: There is no Geological seismotectonic event discovered, but the presence of pottery embedded in the 4m below sand soil could reveal the archeological event of palaeoeartquake.

![Image](image-url)

**Fig 4.23 (Not of scale. Bench mark Human hand) Collection of pottery sample to relate with archeologically important evidence with palaeoseismic event.**

4.2.6 Site name: Batha river section (Loharghat)

**Location:** (91°28'43.9061"E 25°57'17.8481"N)

**Background:** study area Loharghat village near Bath river site has human settlement area, this village is well connected by Road to Chandubi lake which and is near kulushi forest. To visit Chandubi lake one has to pass the Lohargaht village, the memory of 1897 earthquake is still in there remembrance. Batha River is famous for high flow mountain river from
Meghalaya portion to Assam part, where local Garo people use to enjoy ancient traditional Rafting as sports. Local source

**Tectonic Setting:** The Logharghat village like Jagi site falls in the periphery of almost N-S Kulsi lineament in the northern part of Shillong Plateau and southern margin of E-W Brahmaputra lineament. This site is located to north of 1897 Earthquake lake Chandubi

**Trenching:** Trench had been excavated in the Batha river section near Loharghat northern part of Shillong plateau, which have direct impact of Kulsi fault, In its north Brahmaputra liniment passes E-W direction, which reveals a liquefaction structure (Sand Dyke) of fine sand. Fig 4.24

**Identification of Events horizon:** Due to moisture contain in the sediments it is not possible to distinguish multiple events if any; it was too hard to identify the sedimentary structure and to isolate sedimentary deposits with seismic deposit. Although clay was available in deformed patches and only single event can be concluded in this section. Sample is collected for laboratory study.
4.2.7 Site name: Kamakhya Temple Site

Location: (91° 42'44"E: 26° 09'57"N) (Fig 2.2 Chapter- II)

Background: The Tantra Kamakshya Temple is a Shakti Peeth temple situated on the Nilachal Hill of Guwahati city in the south of Brahmaputra river in Assam, India and falls in the north-eastern part of Shillong Plateau. The archeologically Kamakshya Temple in Assam symbolizes the "fusion of faiths and practices of Aryan and non-Aryan elements in Assam (Kakati 1989, p38 ) There existed a tradition among Garos, a matrilineal people, offered worship at the Kamakhya site by sacrificing pigs (Kakati 1989, p37). It is likely that this is an ancient Khasi sacrificial site; Even today devotees come every morning with goats to offer to Shakti. According to the Kalika Purana, Kamakshya Temple denotes the spot where Sati's yoni fell after Shiva danced with the corpse of Sati. According to a legend the Koch Bihar royal family who was looking after temple was banned by Devi
herself from offering puja at the temple. By the end of 1658, the Ahoms under king Jayadhvaj Singha had their interests in the temple grew. Being the centre for Tantra worship this temple attracts thousands of tantric. During the Ambuvaci festival each summer, the menstruation of the Goddess Kamakhya is celebrated. During this time, the water in the main shrine runs red with iron oxide resembling menstrual fluid.

The current temple structure was constructed in 1565 by Chilarai of the Koch dynasty in the style of medieval temples. According to history the form of the earlier structure destroyed by the worrier Kala Pahar, is unknown. Ancient books such as Kalikapurana and Yoginitantra late ninth and sixteenth century A.D., respectively. Both these texts mention destruction to the temple of Kamakhya (seventh-eighth century A.D.)

Tectonic Setting: Kamakhya Temple trench site falls in the North eastern margin of Shillong plateau which might have tectonic control by Kulshi fault in the western part of it, which plays major role in earthquake Lake Chandubi, in its north runs Brahmaputra fault/lineament. Whereas in the south eastern part have Barapani sheer zone which is followed by Kopili lineament in the extreme eastern out part of shillong plateau.

Trenching: On the basis of ancient book about destruction nod, Trenching attempt is done in a section, due to reconstruction of drainage nearby temple we got opportunity and permission to excavate the site fig 4.25
excavated at the temple of Kamakhya, which ingrained the abovementioned textual evidence of destruction. The modern temple sits at the present surface level, on a foundation made of bricks. The Plinth (brick structure) is found broken and covered by debris of about 1.5m above. The middle horizon reflects massive destruction of the previously existing temple structure. Which later construction bricks structure is found followed against by debris above bricks, and finally concrete floor above Fig 4.26.

**Identification of Events horizon:** The trench alternate brick, debris, brick etc profile has an indication of demolition and reconstruction several time may be sixth–eighth century A.D supported by Ancient books such as Kalikapurana and Yoginitantra, also by 1897 earthquake but nothing can be concluded till laboratory analysis is done, so samples of pottery from this assorted layer and the bricks from the bottommost have been collect for TL dating. The lower debris in the Kamakhya temple contains many large sized curved stones resting above the brick wall and needs explanation for their origin.
Fig 4.25 Kamakhya Trench site. Brick, cluttered stone, pottery soil in the profile is visible.

Concrete slab

<table>
<thead>
<tr>
<th>Sample point</th>
<th>Broken bricks, Curved stone and pottery</th>
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<tbody>
<tr>
<td>0.37m</td>
<td></td>
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<tr>
<td>0.79m</td>
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<tr>
<td>1.63m</td>
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<td>1.82m</td>
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<tr>
<td>2.32m</td>
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Fig 4.26 Complete profile of Kamakhya trench site with the location of sample point, the section show from ancient brick underlying debries of potteries and broken sculptures beneath two layers of brick and soil before concrete slab. Repetition of bricks in the profile indicates events of demolition and reconstruction of temple or temple premises.
4.2.8 Site name: Sarthebari Barpata

Location: (91°13'9"E 26° 22'17"N ) (Fig 2.2 Chapter- II)

Background: Sarthebari town is located in the easternmost corner of the Barpata district famous for the household brass metal industry. Large number of households carry out this industry that expertise in making Sarais, Bota, Ban-Batis, Thals, glasses etc. that are traditionally used by the Assamese people. The terrain is reach in sediments deposits. Villager believe (Local source) that the area had mass destruction during past earthquake, It is also believe that various small ponds of Sarthabari is the result of the past earthquake ground shaking and subsidence. (Local source)

Tectonic Setting: Sarthebari situated in the northern part of Shillong Plateau and comes in an alignment of Brahmaputra lineament, in it south west it has two major fault named Chidrang and Dudhnoi fault. Where as in the south east it has Kulshi fault. the probable epicenter of 1897 earthquake lay in southern part of Sarthabari near Dudhnoi fault, the terrain is reach in river recent sediment deposits

Trenching: Trenching was done in few possible location, but not much significant palaeoseismic signature is seen, The trench section shows absence of clay bed, Clay layers plays an important role in the preservation of palaeoliquefaction structures and does not allow seismic deposit to mix with host deposits and so it becomes easier to identify. But
in few sections on close observation it is seen that there are evidence of ground shaking indicated by deformation of sand layers. This presence of deformed sand layers and mini sand dyke express the seismotectonic suffering of the region Fig 4.27

Identification of Events horizon: There is no distinct event horizon identified in this location as the area is poor in seismic tectonic structure preservation.

Fig 4.27 above and below (Bench mark pen 12cm and scale) above and below section showing mini duke like structure and sand bed deformation possibly due to ground acceleration.
4.2.9 Site name: Hajo

Location: (91°34'12.054"E 26°15'24.9653"N)

Background: Located on the North bank of Brahmaputra River around 24 km from Guwahati in Assam, Hajo is an extremely important destination for Hindus, Muslims and Buddhists. Hajo pond of huge turtle temple is important for both the Hindu and the Buddhist community. Within the temple is an image of Vishnu resembles Jagannath Temple in Puri in Orissa. The temple suffered destruction at the hands of warrior Kalapahar who was also responsible for destroying Kamakhya and other temples in India. Later, in the mid 16th century, the temple was reconstructed by the Koch king.

Tectonic Setting: Hajo trench site falls in the Northern margin of Shillong plateau, may have a influence of major faults like Kulshi fault, north runs Brahmaputra fault/lineament. Kopili lineament lays in the extreme eastern out part of shillong plateau.

Trenching: Attempt was made to trench in various place in search of palaeoseismic event but no such convincing structure has be demarcated. Infect sand dyke like structures are seen but on investigation no source mother bed is found supporting the dyke. Finally it has been interpreted as fracture filling Fig 4.28 or animal's actives like Crab hole which were filled with recent sediments of river during flood.
Identification of Events horizon: There is no seismotectonic evidence present in the area, uniform diameter dyke like structure which is found indicate animal activities, the source silt bed laying over the dyke supporting the fact.

Fig 4.28 (Bench mark geological bag of 45 cm) section showing Crab hole along fracture giving impression of seismotectonic palaeoliquefaction sand dyke in the body of clay bed, this reverse dyke is formed due to gravity fill by flood water as the source silt bed is laying on the top of dyke and field observation of dyke silt resembles nearby Brahmaputra river silt and the Hajo area is prone to flood during monsoon.
4.2.10 Site name: Rangapani (Mankachar)

Location: (89° 54' 23.9"E 25°33'25.4"N) (Fig 2.2 Chapter- II)

Background: Rangapani (Mankachar) is famous for the historical remnants of general Mir-jumla, the Army General of the great Mughal Emperor Aurangzeb. Mankachar is located in the Dhubri district of the north-eastern state of India, Assam. Strategically located on the Indo-Bangladesh border, the place is bestowed with attractive scenic beauties. Both the banks of river Brahmaputra with its lush green fields, blue hills and hillock. The Gurdwara Tegh Bahadur Shaibji, the Rangamati Mosque, Mahamaya Dham, Chakrasila wildlife sanctuary and the royal palaces attract the people for their unique structures, religious sanctity and mythological importance. It has Chakrasila Hill Wildlife Sanctuary and Two world famous Wetlands - Dheer Beel and Diplai Beel adjoin Chakrasila wildlife Sanctuary. The area was affected by 7.1M earthquake during 1930, local geology and damage pattern, suggest that N-S Dhubri or Jamuna fault was the source of this event (Nandy, 2001) which lasted for three to five minutes as reported from different places. It was preceded, for a period of several seconds, by a rumbling sound, which was described as an approaching train, thunder, passing motorcar etc. by the observers at different places. A number of clocks in the town were reported to have stopped at 2-35 to 2-37 A.M July 3, 1930, Indian Standard Time (IST).

Tectonic Setting: Rangapani site is situated south western margin of Shillong plateau and is bounded by major faults, it has influence in
alignment of Dapsi Fault trending almost E-W, the tectonic setting of this trench site show the presence of Dhubri Fault in the western part and Dudnoi fault in the east. Dhubri fault was responsible for the 1930 yr 7.1M major earthquake in that area. 1897 earthquake created Chidrang fault fall in the northeast margin with respect to Rangapani trench site.

**Identification of Events horizon:** The trench shows high tectonic influence in the area with well preserved signature. Various size and shape of sand blow are seen. Samples are collected from the site to understand the possible event date. Multiple Seismic events have been observed with distinct episodes. The light blue sand layer Fig 4.29 has subject to palaeoseismic deformation and a clear sand dyke (Dyke-1) is seen which is well preserved in the bed of brown sand layers, the liquefaction flow is well preserved in both the mother sand bed and the dyke. The flow direction can also be seen in the junction of the dyke (dyke-1) and source mother -1. The brown sand layer also is highly deformed and also behaves as mother sand source bed for dyke -2 and other half expose dykes in the background of the trench section Fig 4.29. It is also noted that in the right hand side of the trench section a dyke-3 is exposed and have penetrated all the deformed beds crosscutting all the bed structures Fig 4.30 and looks like younger event in the section. Detail documentation and sampling have been carried out in each trenching site for laboratory study.
Fig 4.29 (Bench mark measuring scale) multiple event can be seen in the trench section with respect to multiple layers well connected with mother sand source bed with distinct colour of fine sand. The dykes are of various size and shape can well be represented by this trench site. The sand beds are highly deformed and palaeoliquefaction flow is distinct in case of dyke 1 and mother source sand bed 1 and its junction. The brown colour sand bed is highly compressed due to palaeoseismic ground acceleration which can also be seen in almost all beds of this section.
Photo 4.30 (Bench mark measuring scale) Section is showing a dyke which has cut all the strata structure and blow upward indicating younger event in the section.