A GEOLOGICAL FIELD REPORT ON JAINTIAPUR, SYLHET.

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Abstract

The investigated area known as the Jaintiapur area within the Sylhet District lies in the northeastern part of Bangladesh and occupies exposures of a continuous Cenozoic stratigraphy of the Sylhet trough within the latitude of 25˚5'N to 25˚12'N and the longitude of 92˚E to 92˚12'E. The Sylhet trough contains a thick fill (12 to 16 m) of late Mesozoic and Cenozoic strata that record its tectonic evolution (Johnson and Alam, 1991). Jaintiapur area covers the foothills of the Khasi-Jaintia hill range and is features by high and low altitudes in the north and south respectively. The Sylhet trough is tectonically a complex province of the Bengal Basin. The configuration of the Sylhet trough is thought to have come into existence during the late to post-geosynclinal phase of tectonic evolution of the Bengal Basin, partly as a fault bounded trough, subsiding from Oligocene or earlier times towards with its peak of subsidence since Pliocene (Holtrop and Keizer, 1970).

The investigated area is characterized by several types of rocks. Eight lithostratigraphic units were identified upon observing these rocks. These units from Oldest to Youngest are Unit-A (Fossiliferous Limestone), Unit-B (Dark Black Shale), Unit-C (Pinkish Sandstone), Unit-D (Silty Shale), Unit-E (Alternation of Sandstone and Shale), Unit-F (Yellowish Brown Sandstone), Unit-G (Mottled Clay), and Unit-H (Variegated Colored Sandstone). The petrographic and grain size analysis of the samples collected in the investigated area corroborates the correlation of these units with the stratigraphy of Surma Valley (Evans, 1993) which denotes the observed units as Sylhet Limestone, Kopili Shale, Barail, Bhuaban, Bokabil, Tipam, Girujan Clay, and DupiTila formations respectively,

Lithology, analysis of the Sedimentary structures and petrological studies prove that the investigated area were deposited from Shallow Marine to Fluvial environment.

The Sylhet Region or Surma Basin is enriched with natural resources such as natural oil/gas, hard rock/gravel, construction sand, limestone, and glass sand and peat coal. The economic value of proven gas/oil reserve is significant to the national demand in the energy sector.

Acknowledgement

Firstly, I would like to express my earnest gratitude to the Almighty for keeping me fit during this fieldwork and for his blessings that made it possible for me to come so far and study in the Department of Geological Sciences, Jahangirnagar University, which allowed me to acquire the immeasurable knowledge about this planet.

Furthermore, I am forever grateful to the authority of our department, Geological Sciences, Jahangirnagar University, for conducting such a highly engaging field work that has enabled us to gain practical knowledge

I want to share my heartiest appreciation towards Associate Professor Dr. Rashed Abdullah, Associate Professor Zahidul Bari, and Associate Professor Dr. Abu Sadat Md. Sayem for their incalculable advice, close guidance and valuable discussion about the field report. I have no words with which to convey my thanks for all their help and motivation that has led me to successfully finish this field report.

Special thanks to 'Jaflong Picnic Center Restaurant' for making us feel so welcome and for providing such a cozy and comfortable stay in the guesthouse without whose help it would been tough for us to carry on.

Finally, my heartiest gratefulness goes to my classmates for their tremendous support and collaboration.

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Chapter 1 Introduction

The Sylhet trough of the Bengal basin is located in the eastern part of the Indian Subcontinent. The trough occupies a vital geographic position at the junction of three interacting plates, namely, the Greater Indian, Burmese and Tibetan plates and accommodates an approximately 17 km thick Cenozoic (Eocene to Recent) sedimentary rocks (Hiller and Elahi, 1984a). Sedimentation in the Bengal basin (including Sylhet Trough) has been controlled by the uplift and erosion of the Himalayas and Indo-Burman Ranges which was formed due to the collision of the Indian Plate with the Burmese and Tibetan plates (Alam, 1989) and later is linked with the uplift of the Shillong Plateau (ref).

Jaintiapur area within the Sylhet District occupies exposures of a continuous Cenozoic stratigraphy of the Sylhet Trough within the latitude of 25˚5´N to 25˚12´N and the longitude of 92˚E to 92˚12´E (fig). Unfortunately, the stratigraphy of the Sylhet Trough or the Bengal Basin is not well established and has been correlated with the stratigraphy of the Assam region (Evans, 1932) which has different tectonic history.

Thus, the Jaintiapur area carries a significant value in understanding the stratigraphy, tectonics, basin-fill history of the Bengal basin. Therefore, the purpose of this study is to apply modern concepts of field mapping, sedimentology and structural geology to produce a high-resolution geological map, to construct a lithostratigraphy of the investigated area and to depict major structural features in both map and section views. For geological field mapping, traversing has been used.

1.1 Location and Extent

Jaintiapur and adjacent areas lie in the north-eastern part of Sylhet district, lies in between latitudes of 25°5´ N to 25° 11´ N and the longitude of 92°0´ E to 92°11´ 15´´E. (app). Jaintiapur covers the foothills of the Khasi-Jaintia hill range and is featured by high and low altitudes in the north and south respectively.

Geographically the area extended from Dauki River in the north, Hari River in the south and Jaflong in the west. Jaintiapur is at the foot of Khasi and Jaintia Hills of Shillong Massif. Along to the following two sections our field work was preceded-

- Dauki- Tamabil- Sripur Tea Garden- Nayagang Section
- Sari River and Dupigaon Section

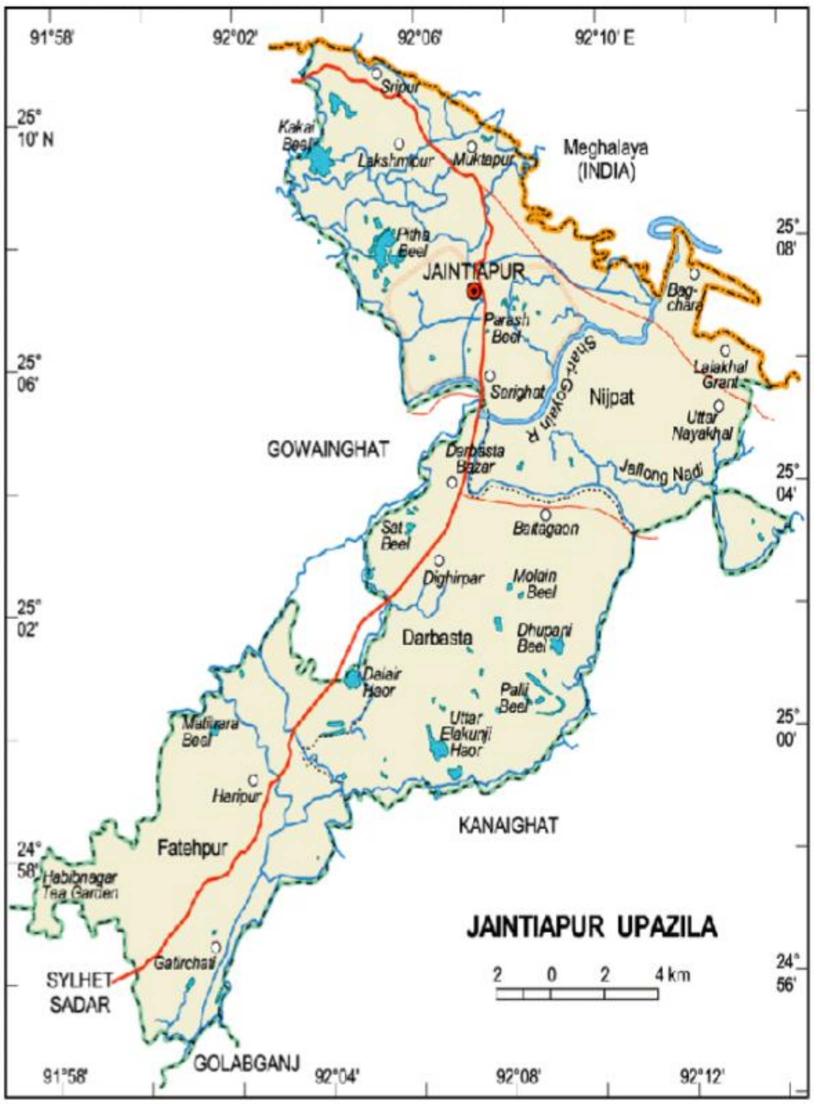


Figure 1 Location Map of Jaintiapur Upazilla

1.2 Accessibility

The Jaintiapur and adjacent areas comprise about 147 square km, 14 km in the east-west direction from Balla Ghat to Afifanagar and 11 km in north-south direction from TamaBil to Shari Ghat. Jaintiapur is linked with Sylhet town by a metaled road. It is about 45-km northeast of Sylhet town. The Sylhet town is well connected to Dhaka, the capital city of Bangladesh by road, railway, and also by air.

The metaled road goes up to Jaflong through Sripur and TamaBil. TamaBil is about 60 km northeast from Sylhet and Jaflong is 45 km from TamaBil. Jaintiapur can be reached by bus which goes to Jaflong. The Sari River is connected with Jaintiapur by mud track. A mud track also runs from Jaintiapur to Mahismara Bil along the Nayagang River.The exposures can be found easily along mud track or foot track.

1.3 Methods and Equipment used in the Field

Methods of Investigation: The traversing & spot location methods were used for the survey in the field which was carried out along the sections where the rocks are well exposed. The distance was measured by traversing system which is known as steeping. The attitude of the beds were measured by Clinometer. The information was plotted on the base map to get a clear view of the studied area & outcrop. All the information like bearing & distance of the next location, points of lithologic contact & sample, attitude of beds, other structures, lithology, physical feature etc. were noted down on a field note book. Photographs were taken in every location & other suitable geologic elements.

Equipment used in the field: Geological field works demands high degree of sincerity and enough labor. Some equipment is necessary to complete the field work. The following equipment were used in the field to help for proceeding on this investigation-

- **Base map:** A topographical base map for Jaintiapur and adjoining areas of Sylhet district with a scale of Scale 1:12,000 to locate the selective areas & to plot the dip & strike reading.

- **Clinometers:** It is for measure the dip, strike and dip amount of the bed.
- **Hammer:** To collect samples and to find out the proper beds and other sedimentary structures.
- **Sample bag & rubber band:** It is used to collect rock sample of individual stations with proper labeling and to prevent the sample from air.
- **Sample identification slip:** To indicate particular sample in particular location.
- **Acid bottle:** It contains dilute HCl, which is used to determine the presence of calcareous constituents within the rock bodies
- **Measuring tape:** It is used to measuring the distance
- **Pocket Lens:** To observe the texture (shape and size) of the rocks.
- **Camera:** To take photographs of the geological feature of the section.
- **Global Positioning System (GPS):** It is used to determine longitude, latitude, altitude of different section.

1.4 Purpose and Scope

The principal tasks of the field geology is studying systematic sampling and geological mapping covering aspects of petrology, sedimentology, stratigraphy and structural geology in order to develop independent working ability.

The field work is done where the rocks and their necessary structural and stratigraphical features are easily observed and studied in their natural environmental condition by some methods to examine and interpret structures and materials at the outcrops.

Generally geological field investigation reveals the following information:

i. By field investigations geologic map can be prepared from base map.

ii. To effectively apply the theoretical knowledge of geology in field and acquainted with field investigation techniques, the way to learn geology.
iii. Both the structural and geologic features such as fold, fault, joint, unconformity, gorge, waterfall etc., which are determined by the attitude and lithologic observation
iv. Benefits of field work is to know the nature of sedimentary rocks, sedimentary structures, such as ripple marks, cross-bedding, bioturbation, concretion, etc., and the condition of deposition of sediments.
v. Geological field investigation helps to know about the stratigraphy and correlate the observing section with a standard geologic column.
vi. The study gives us idea of local economic resources.

1.5 Previous Investigations

The Sylhet district together with the investigated area has been said to be highly prospective of oil and gas from many years. Large number of works have been done on the studied area. For this reason, in Sylhet, large volume of exploration work-geological, geophysical and drilling activities carried out since 1923 by different organizations and Barma oil company (BOC) had been the pioneer. Three more oil company namely Pakistan Petroleum Ltd. (PPL), Pakistan shell oil company (PSOC) and stanvac oil company (SVOC) joined in later (Dr.Guha, 1975).

Many geologists had been worked on Sylhet through. The work data back to early fifties of the century, when Evans P. (1932) first published the stratigraphy of the Tertiary succession in Assam which is considered as the Bible to the stratigraphy of the region till today. Among the geologists Holtrop J.F. and Keizer J. published a correlation chart “Chart of Surma Basin Wells” in 1966. They stressed and poorly exposed in the form of “Upper Marine Shale” in the Surma Basin for correlation within the basin.

Maroof Khan, M.A. (1978) published a report and a reconnaissance geologic map in the scale 1 inch to 1 mile of the eastern and north-eastern Surma Basin. The map embraced the whole Tertiary succession of the area except the Sylhet Limestone which forms inliers in the east bank of the Dauki River.

Palynostratigraphic analysis of Oligocene outcrop sample was done by Wallid K.M. (1982), Reimann, K.V. (1983).Wallid's palynological investigation and Reiman's (1983) on the sub-crop have clearly revealed the presence of Oligocene forms.

Haque, M. (1982) studied the development of Surma Basin and its relations to hydrocarbon accumulation. He developed a scheme of palynological zonation of the Cenozoic succession in the Surma Basin. He also reviewed the exposed and subsurface stratigraphy of Surma Basin.

Hiller and Elahi (1984) published the structural development and hydrocarbon entrapment in the Surma Basin. They concluded that the Surma Basin is a proven Miocene Gas province and was structurally stamped by the contemporaneous interface of the major tectonic movements.

Khan et al. (1988) reveals that the gases discovered in the basin are genetically similarly to each other and are generated probably from terrestrial kerogen at various levels of maturity equivalent to approximately 0.6 to 1.5% vitrinite reflectance oil from Patharia and Sylhet have similar characteristics and may have sourced from the Oligocene sediments.

Paul, D.D (1988) revised the structure and tectonics of the north-eastern part of the basin and commented that the east-west trending structural feature (fault) were developed by the forces, resulting from the under thrusting of the Indian plate towards NNS direction where it collided with the Eurasian plate.

A comprehensive seismic grid and structural inventory respectively was established for the first time in the Surma Basin with German Technical Assistance performed in 1979 and 1982 (Elahi and Hiller, 1984).

The Surma Basin was also studied by M.A. Maroof Khan of Petro Bangla, Monwer Ahmed of BAPEX. This area was also studied in details by D. K. Guha of Petroleum Institute.

The area was also investigated recently by a number of students supervised with their teachers of the Geology Department of Jahangirnagar University, Dhaka University and Rajshahi University.

Chapter 2: Physical features of the Study Area

2.1 Topography and Relief

The investigated area is bounded from west to east by Khashi-Jaintia hill range and is bordered on the northeast by abrupt scarp of the 4000 to 6000 feet high Shillong plateau. The region is almost hilly. Numerous low to moderately elevated hillocks are present here.

The average elevation of the area is about 60 to 340 feet. Maximum elevation is found at Lalakhal area and minimum in northwestern region. The hilly area does not comprise continuous heap of rocks but also furrowed by numerous valleys giving the landscape of a rugged look. The area embraces two major types of landforms. The investigated area exhibits moderately hilly topography. The hills having low to moderate elevation are almost East-West trending. Four prominent hillocks are found in the studied area. These are locally known as "Tila". The most prominent is the Sonatila in the northwestern part of the area located on the bank of Dauki River. It is about 214 feet in height.

Figure 2 Topography of the Study Area.

Towards east another prominent Tila is located in the Tamabil region with the highest peak of 200 feet. Sripur Tila marks middle portion of area. Dupitila is in the southwestern part of the studied area and it should be specially mentioned because this is the hillock after which the formation of Dupitila named. The height of this hillock is about 301 feet.

The rest of the areas are flat alluvial land. A large plain covering several sq. miles between Jaintiapur and Dupitila is locally known as Boga Bil, Bally Bil. These bills lie mainly on the valley of the Hari River used for cultivation during dry season. During the flood these low-lying area totally undergo into water.

2.2 Drainage System

The area is well drained by network of locally important streams. The important rivers of the area are the Hari River, Dauki River etc. Dauki originating from southeastern part of Shillong Plateau encroaches southeastern part of the Dauki town, India and flows into Bangladesh in north-south direction.

Dauki is another most important rivier flows in a meandering pattern towards south-west direction. This is a fault controlled, perennial river. This river also originates from Khashi- Jaintia Hills, Meghalaya, which carry largest boulders in the rainy season from Shillong plateau. Due to low slope, the river dumpy drops into carrying materials of different shaped boulders whitch come out from Shillong Plateau and from the adjacent hilly range. The water of this river is only the source of drinking water for the local people. The shallow water permits the limit of navigation.

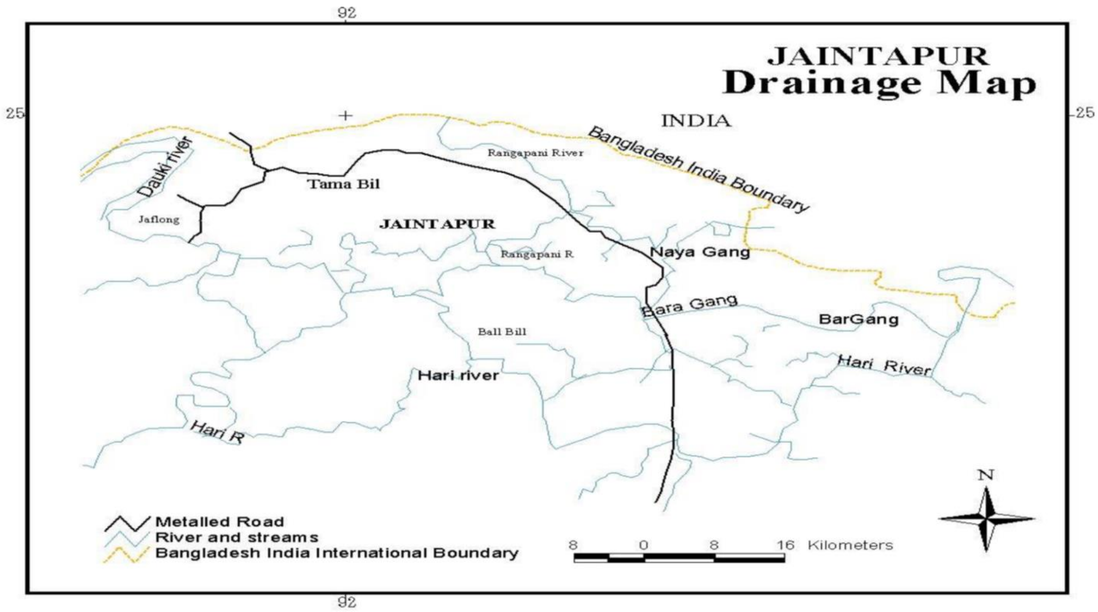


Figure 3 Drainage map of Jaintiapur

2.3 Climate

The climate of the investigate area is usually tropical to subtropical in character marked by uniform temperature, high humidity heavy rain from May to October. The climate is thus moist, worm equable. There are three distinct seasons in the Jaintiapur area. They are described below-

The Summer: Begins from March continues up to May with moderate precipitation.

The Monsoon: Starts from June & lasts till October. During Monson the sky is often overcast with dark clouds, and it rains heavily accomplished by gusty wind & occasionally with a cyclonic storm.

The Winter: It begins from November & continues up to February, with a pleasantly cool, clam, & dry weather. We went to the area that we investigated at the winter season.

2.4 Vegetation and Cultivation

The tropical to sub-tropical climatic condition of the investigated area provides sufficient precipitation and heat favoring the luxuriant growth of evergreen forests. Hillocks and slopes of this area are covered by thick vegetation.

Important trees of the investigated areas are Shimul, Champa, Chapalish, Teak betel nuts etc. Tall grasses and Bamboo also grow in this hilly region. High rainfalls, moistures, and wind together with vast alluvial plains is responsible for cultivation and dense vegetation.

The total cultivable land is about 63,932 acres. Bills, khals and other low-lying areas are used for Boro cultivation. Hari River bank was under watermelon cultivation. Orange and pineapple gardens are present in some areas. This area is suitable for tea cultivation. Huge amount of tea are produced in this area.

When we investigated this area, we saw a lot of tea gardens. A series of tea gardens are situated in hillocks and valleys from Jaflong to Afifanagar. A lot of fruits such as jackfruit, papaw, and banana are also grown here. Other seasonal crops like tobacco, oilseeds and vegetables such as pumpkins, beams are also grown in this area.

Figure 4 Vegetation and Cultivation in the Study Area

Chapter 3: Geological Setting of the Area

3.1 Tectonic Elements of the Bengal Basin

Bengal basin was developed during Late Cretaceous. The tectonic elements of the Bengal basin is given below:

- Stable platform (W-NW trending).
    - Northern slope of Rangpur saddle.
    - Rangpur saddle.
    - Southern slope of Rangpur saddle.
- Paleo continental slope / Hinge zone (NE-SW trending)
- Geosynclinal basin (E-SE trending)
    - Foredeep in the West
        - Faridpur trough
        - Hatiya trough Low
        - Surma basin

        Low

        - Barisal Chadpur gravity high
        - Madhupur Tripura threshold High
        - Tripura uplift

        High

    - Fold belt in the East
        - Western zone
        - Eastern Zone

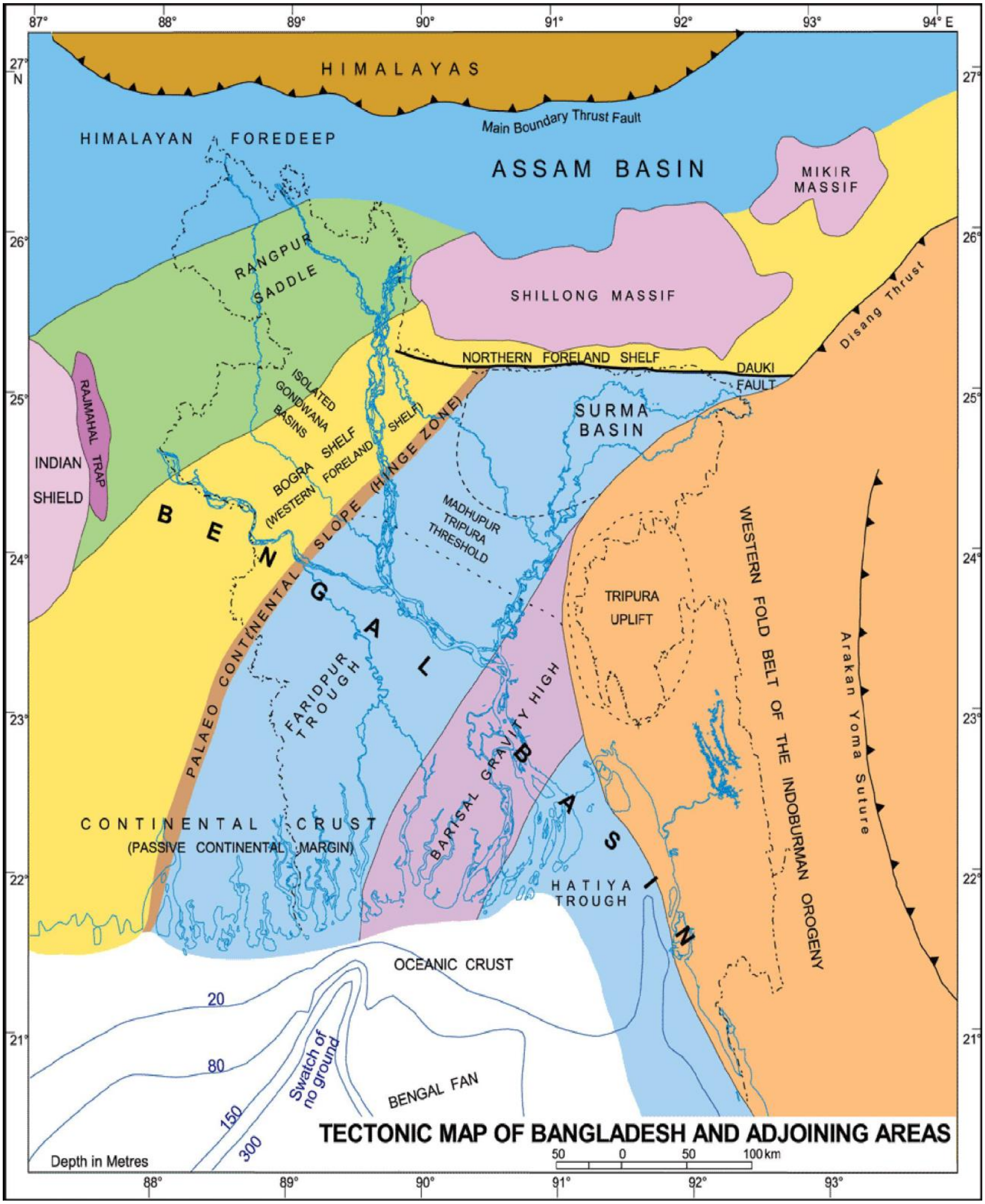


Figure 5 Tectonic map of Bangladesh and adjoining areas (Guha, 1978 and Reimann, 1993)

3.2 Structural setting of the Investigated Area

The Bengal Basin is divided into foreland shelf and Foredeep separated by continental slope (Guha, 1978 & Saltet et al., 1986). The Surma Basin is a northeastern trough of Bengal Foredeep. It is bounded in the north by the Shillong Plateau, in the west by the continental slope and in the south it is separated from Faridpur Trough (a sub-division of the Bengal Foredeep) by Madhupur. Tripura threshold (Reimann, 1986 and Matin et al., 1986).

The Surma basin is a structural depression which is oval in shape with a length of 130 km and a width of 60km forming the northern extension of the Bengal Basin. It began to subside from the Oligocene Age with its peak of subsidence in Pliocene Age (Holtrop & Keiser 1970). The area has been subjected to additional forces from the north and south-east. The north to south stress placed on the Shillong Massif following the collision of Indian plate and the Eurasian plate has resulted in reversal of the direction of movement along the Dauki Fault. This has resulted in upliftment of Shilling Massif and Subsidence of the Surma Basin. The study area lies in between these two contrasting structural set-up, and bounded by the Khasi-Jaintia hills and Shilling Massif in the north, Goyain trough in the south, Atgram anticlinal structure in the east and Goyain Trough and foot hills of Khasi-Jaintia range in the west [Bangladesh Geoscience Journal, Volume-2, Page-14].

Jaintapur and adjoining area is our Investigated area fall in the Surma basin (Sylhet Trough) of the Bengal foredeep of bangle Basin. The Sylhet trough, lying at the northern part of the folded belt, ascends gradually towards the Hinge Zone in the west, while passing toward the Bengal foredeep. The Sylhet trough is a tectonically complex province of the Bengal Basin. The configuration of the Sylhet trough is thought to have come into existence during the late to post-geosynclinal phase of tectonic evolution of the Bengal Basin, partly as a fault bounded trough, subsiding from Oligocene or earlier times towards with its peak of subsidence since Pliocene (Holtrop and Keizer, 1970) . It is also believed that the structural development of the trough is related to contemporaneous interference of two major tectonic events:

- Emergence of the Shillong Massif in the north that was accompanied by creation of Dauki fault system.
- Westward prorogation of the Indo-Burman fold Belt.

This sub basin covers an area of roughly 10,000 km2 and is bounded on the north by the Shillong plateau on the east and south-east by the Tripura-Chittagong fold belt and on the west by the hinge zone the trough is open to the southwest and south to the main part of the Bengal Basin.

The northern Shillong Massif is highly elevated block lies entirely on Indian Territory but its southern fringes form a narrow strip of hills and hillocks in Bangladesh territory. Our Studied area is the part of the region and located at North-East corner in Bangladesh and Along the Bangladesh Indian Border.

The area is bounded by the major E-W trending Dauki fault towards north, whichis still active. A continuous series of hills of this area stretches from the Jaflong River (Dauki River) to the south – eastward direction. The western edge of this hilly strip, located between the Jaflong River and the town of Jaintapur, is made up of block faulted Eocene and Oligocene sediments, whereas the hills and hillocks located east of jaintapur consist solely of Neogene deposits. The alignment of these elevations parallel to the general strike of the rock formations.

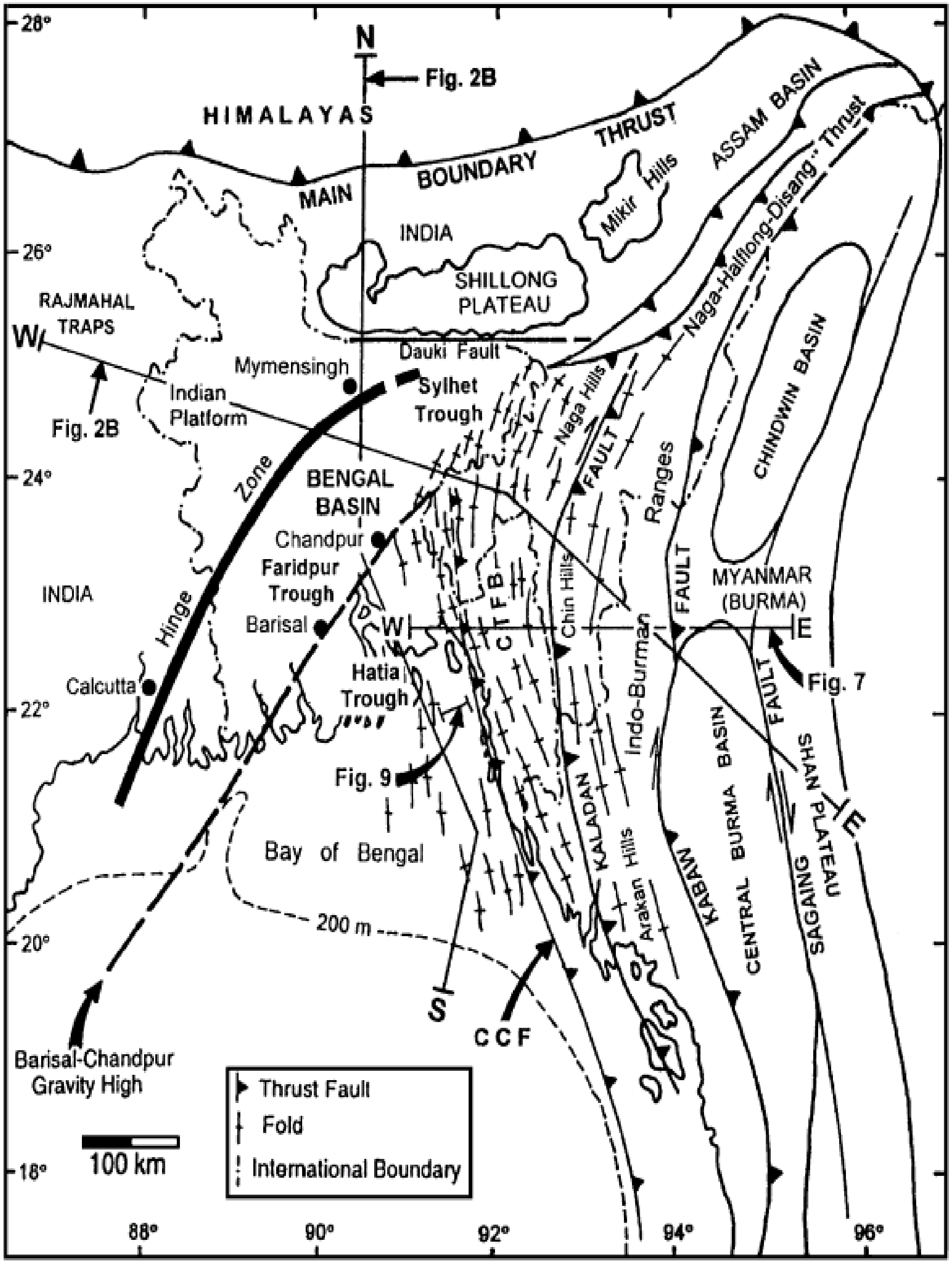


Figure 6 Regional map showing the Tectonic Elements of Bengal Basin and surrounding areas (Hossain, 2003).

The Hinge zone, lying above the Calcutta–Mymensingh gravity high, separates the Stable Shelf. CTFB = Chittagong–Tripura Fold Belt and CCF = Chittagong–Cox's bazar Fault.

3.3 Geological Evolution

According to the continental drift theory the super continent Pangaea divide into two parts. One is Gondwana and other is Laurasia. The separation of East Gondwanaland comprising India, Australia and Antarctica took place into three major stages.

The first contract of the northwards moving Indian Plate with the Eurasian Plate took place in

Paleocene/Lower Eocene. Subsequent subduction led to the formation of an ophiolite and mélange belt and later to the rising Indo-Burman Orogeny. The latter finally separated the Burmese basins in the east from the Bengal Basin in the west.

The eastern margin of the Bengal Basin coincides with the frontal Fold Belt of the Indo-Burman Ranges. Molasse like Miocene-Pliocene deposits were folded into a series of elongated, generally N-S striking anticlinal and synclinal structures. The Fold Belt stretches from the Chittagong Hill Tracts in the south east to the southern edge of the Shillong Massif in the north, traversing the Indian state of Tripura and the eastern portion of the Surma Basin *(Reimann, 1991).* After the Pre-Cambrian era, the history of the basement complex was one of the peneplanation until Permo-Carboniferous time when Permian, Mesozoic and Gondwana sediments with coal accumulated in the western side of the basin. The breakup of Gondowanaland led to the eventual separation of peninsular India from the southern continents, permitting a Cretaceous marine transgression (Alam 1989).

The Bengal Basin has been in filled with sediments from the north, east and west. During this process, the basin has generally deepened and the sea level has varied considerably from its present position. During the Cretaceous Period, the sea transgressed northwards towards the southern edge of the Shillong plateau and subsequently regressed far south into the Bengal Basin, causing at least four major transgressions and regressions. Argillaceous and arenaceous deposits accumulated on the stable shelf zone in freshwater to littoral facies. The sedimentation at the same time in the fore deep and mobile belt was marine, at least during the late Cretaceous (Alam 1989). From the Paleocene to the early Eocene, the shelf was subjected to repeated submergence and emergence marked by the Tura Sandstone (240 m). Extensive marine transgression took place in the Middle Eocene and the hinge-line was initiated due to a deeply seated basement fault between the stable shelf to the north – west and a geosynclinal trough to the south – east (Raju 1968). The Nummulitic Sylhet Limestone was deposited over most of the shelf area (about 245 m) in a shallow clear water and open marine shelf environment in a warm climate.

During the Late Eocene Period, the Kopili Formation (238 m) consisting of carbonaceous pyritic shale and glauconitic sandstone (Ahmed & Zaher 1965) was deposited in a brackish to marine environment. The formation contains micro foraminiferal assemblages of Globorotalia cocoensis biozone (Khan & Mominullah 1980).

During the Paleocene to Eocene period, the Jaintia Group consists of three formations: Tura Sandstone, Sylhet Limestone and the Kopili Formation, which were deposited on the shelf (Total thickness is 725 m) in a shallow marine and marine environment.

The upliftment of the Arakan – Yoma – Chin geanticline and basin – wide movement took place in Early Oligocene. The sea regressed from the Shillong Plateau area and fluviomarine Barail sediments were deposited along the southern rim of the Shillong Plateau; at the same time the area extending from the SB to the Chittagong Hill Tracts subsided and was filled with fine grained marine Barail shales and siltstones (Holtrop & Keizer 1969). The thickness of the Barail Group generally decreases towards the shelf. The deposition of the Barail Group in the fore deep basin and the mobile belt varies from 800-1000 m whereas on the shelf it is only 163 m and is represented by the Bogra Formation (Ahmed & Zaher 1965). The thickness of formations here is approximate and varies considerably from well to well.

During the Miocene, a major uplift began in the Himalayas subjecting the Bengal Basin to related tectonic movements (Fairbridge 1983). The deep basin featured conspicuous subsidence and marine transgressions through much of the Miocene. The SG (5000 m) and the Tipam Group (2270 m) were then deposited in deltaic to shallow marine and continental environments, prograding to the southeast with depositional conditions changing to marine (Alam 1989).

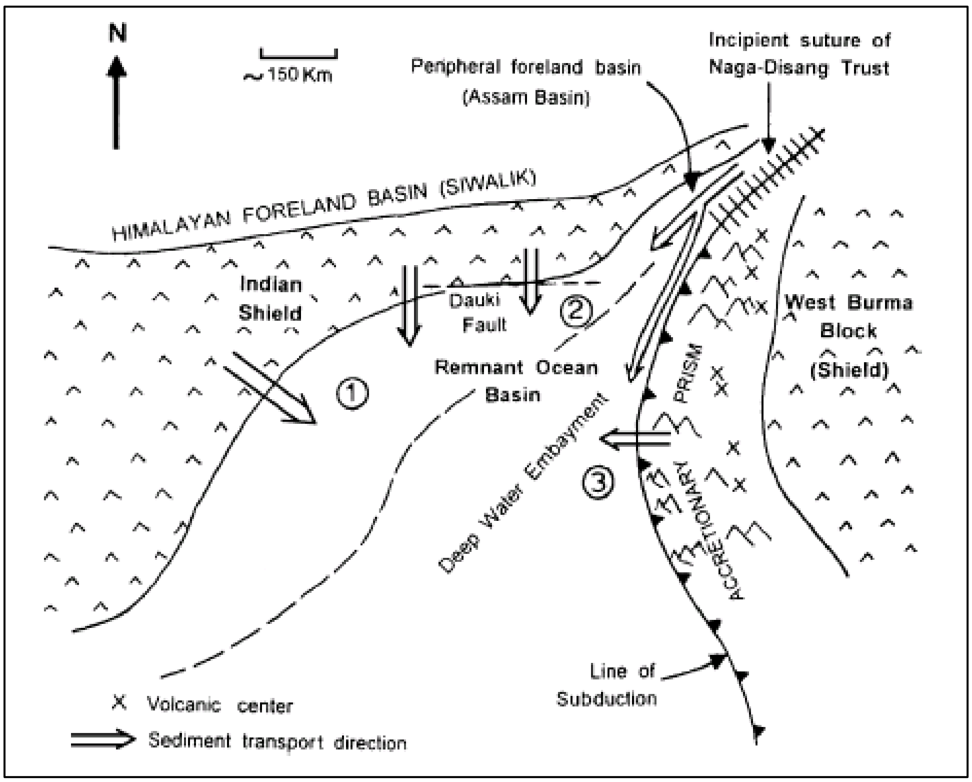


Figure 7 Schematic Early Miocene palaeogeographic representation of the Bengal basin and surrounding regions in terms of the Plate Tectonic Model.

Positions of the three geo-tectonic provinces of the basin are shown by encircled numbers: (1) The Stable Shelf; (2) The Central Deep Basin, and (3) Chittagong- Tripura Fold Belt.

3.4 Stratigraphy of the Investigated Area

The Surma Basin lies in the Province 2 of the greater Bengal basin. The stratigraphic succession of province 2 was initially established by lithostratigraphic correlation to type sections in Assam Basin, NE India (Evans, 1964; Holtrop & Keizer, 1970; Khan & Muminullah, 1980).

On the basis of basin-wide seismostratigraphic correlation, Leitz and Kabir (1982) have partly refined the conventional stratigraphic framework for most parts of the Bengal Basin.

Seismic data indicate that the Sylhet Trough of Province 2 contains about 17950 m of Eocene-Holocene clastic sediments (Hiller & Elahi, 1988) that appear to correspond fairly well with the maximum 17000 m Eocene – Holoce succession in the adjacent Assam Basin (Das Gupta, 1977).

Table 1 Stratigraphic succession of the Sylhet Trough in the Northeastern part of Province-2 (revised from Hiller and Elahi, 1988).

Age (approx.)	Group	Formation	Seismic marker	Thickness (max.) (m)
Holocene		Alluvium		3350
Pleistocene	Dihing	Dihing Upper Dupi Tila		
Late Pliocene	Dupi Tila	Lower Dupi Tila	→ Yellow	
Mid-Pliocene	Tipam	Girujan Clay Tipam Sandstone	→ Brown	3500
Early Pliocene Miocene	Surma	Upper Marine Shale Upper Lower	→ Red → Violet	3900
Oligocene	Barail	Undifferentiated		7200
Paleocene-Eocene	Jaintia	Kopili Shale Sylhet Limestone	→ Blue	
		Tura Sandstone		
Pre-Paleocene	Undifferentiated sedimentary rocks (with some volcanics ?) on the continental basement complex			

Chapter 4: Sedimentary Petrology

4.1 Sedimentary Lithofacies

Lithofacies means the mappable subdivision of a designated stratigraphic unit distinguished from adjacent subdivisions on the basis of lithology. It is those facies characterized by particular lithological features. Sedimentary facies are a mass of sedimentary rocks which can be distinguished and defined from others by geometry, lithology, sedimentary structure and paleo-current patterns and fossils i.e., sedimentary facies are the aspect or the character of the sediment.

Based on our field investigation, we found eight stratigraphic rock units. These are Unit –A (fossiliferous limestone), Unit-B (Dark black shale), Unit –C (Pinkish Sandstone) ,Unit-D (Silty Shale), Unit –E (Alternation of Sandstone and Shale), Unit –F (Yellowish Brown Sandstone), Unit –G (Mottled Clay), Unit–H (Variegated color Sandstone). In total, we observed 18 lithofacies which are described as following:

i. *Fossiliferous Limestone Facies:*

   The Fossiliferous Limestone is non-clastic and very hard and compact. Abundant Nummulite fossils were seen in these sub- facies. The fossiliferous limestone is bedded structured. The Nummulitic fossils are identified in naked eyes with concentric appearance which is classified as macrofossil (see fig-8).

ii. *Non- fossiliferous Limestone Facies:*

   The non- fossiliferous limestone was seen with occasional interbedded black shales. This limestone is characterized by dip and strike joints. The length of the dip joints is approximately 2-3m with a spacing of about 4-5 cm. On the other hand, the strike joints are approximately 15-20 cm long with a spacing of about 6-5 cm (see fig-8).

Figure 8 Exposures of Fossiliferous Limestone (left) and Non- fossiliferous Limestone (right) as seen in Dauki River Section.

iii. *Pinkish Sandstone Facies:*

It is pink in color, fine grained, highly permeable, ferruginous cementing material, hard and compact. The sandstone contains occasional interbedded shale. Parallel lamination, micro-cross lamination, planner bedding, planner cross bedding, trough cross bedding were found. We also found carbonaceous matter, iron incrustation, burrows. These facies are widely spread in Unit –C (see fig-9).

Figure 9 Exposure of Pinkish Sandstone as observed in Tamabil Road Cut Section.

iv. *Trough Cross Laminated Sandstone Facies:*

These facies characterized by pinkish, yellowish-brown color, fine to medium grain, permeable, ferruginous cementing material, hard and compact. Ripple-cross lamination, iron incrustation. This type of facies was observed in Unit-C, Unit-D, and Unit – E (fig-10).

Figure 10 Trough Cross Bedded Sandstone obeserved in Sari River section.

v. *Flaser Bedded Sandstone Facies:*

Grey color, medium to fine grained, the amount of deposited sand exceeds mud deposit observed in Unit-D and Unit-E (fig-11).

vi. *Lenticular Bedded Sandstone Facies:*

Fine grained, greyish colored, argillaceous cementing materials. Mud ratio higher than sand comprises this type of facies. It is found in Shale mainly in Unit- D (fig-11).

Figure 11 Lenticular Bedded Sandstone (left) and Flaser Bedded Sandstone (right) observed in Nayagang section.

vii. *Channel Sandstone Facies:*

Channel Sandstone facies is characterized by medium to fine grained, yellowish brown colored, parallel laminated sandstone as channel lag deposit found in Unit-C (see fig-12).

Figure 12 Channel Sandstone exposure as observed in Tamabil Road Cut Section.

viii. *Yellowish Brown Sandstone Facies:*

Yellowish brown colored, fine to medium grained, moderately compacted, highly porous, permeable, sub-angular to sub-rounded, large-scale cross-bedded, parallel lamination, planar cross-bedding, trough cross-bedding, presence of clay galls, and a very thin layer of petrified wood. This Sandstone Facies was observed in Unit-F.

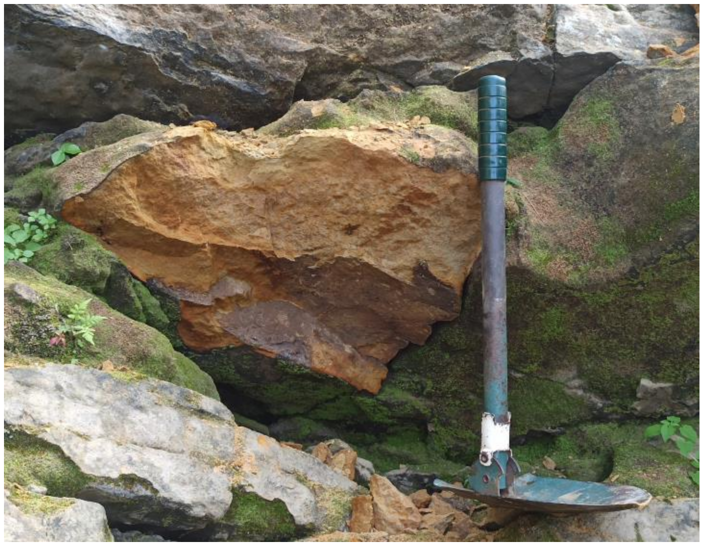


Figure 13 Yellowish Brown Sandstone observed in Nayagang Section.

ix. *Variegated Colored Sandstone Facies:*

Yellowish, pinkish, grey in color; medium to coarse grain sized, loosely compacted, arenaceous and ferruginous cementing materials, highly permeable, rounded, and moderate to poorly-sorted. Sedimentary structures such as massive, trough cross bedding, parallel bedding were found. High content of pebble, cobble, and organic matter was also observed. This unit was identified at Unit- H (see fig-14).

x. *Massive Bedded Sandstone Facies:*

Pinkish, yellowish brown color, moderately hard and compact, ferruginous cementing material, no sedimentary structure developed found in Unit-C, Unit-E and Unit-G (see fig-14).

Figure 14 Yellowish Brown Sandstone (left) and Massive Sandstone (right) observed in Dupigaon and Tamabil Road Cut sections respectively,

xi. *Low Angle Cross Laminated Sandstone Facies:*

Low angle cross laminated sandstone characterized by yellowish brown color, fine to very fine grain size, moderately compact, and the cementing material is ferruginous. We found it Sari-river section which was approximately 25m in thickness in Unit-A. It indicates shore face environment.

xii. *Silty Shale Facies:*

Grey in color, containing mostly clay sized particles and clay minerals, argillaceous cementing materials, lenticular structure with small scale micro-cross lamination, parallel lamination, *ball and pillow structure, iron incrustation, lesigan structure.* This rock type was observed in Unit-D.

xiii. *Dark Black Shale Facies:*

Dark Black in color, clay sized particles, argillaceous cementing materials, fissile in nature, laminated, contains high organic materials like Pelecypod. The presence of high organic contents results in its distinctive dark black color and also makes it feasible for a good source rock. This rock was found in Unit- B (see fig-15).

xiv. Bluish Grey Shale Facies:

Bluish grey in color, clay sized particles, argillaceous cementing materials, occasionally fissile in nature, planar cross lamination, trough cross bedded. Secondary sedimentary structures include presence of carbonaceous matter, Iron incrustation and burrows. This rock type was observed at Unit-C (see fig-15).

Figure 15 Dark Black Shale (right) and Bluish Grey Shale (left) as observed in Dauki and Dupigaon sections respectively. The red line represents unconformity between Dark Black Shale (upper) and Limestone (lower).

xv. Mottled Clay Facies:

Bluish grey in color, clay sized particles, medium to high plasticity, massive structure, and high content of organic matter. Found in Unit- G.

Figure 16 Mottled Clay as observed in Dupigaon Section.

xvi. *Siltstone Facies:*

Grey in color, silt sized particles, moderately hard and compact, inter bedded with mudstone and sandstone. This rock type was found mainly in Unit- D and Unit- G.

xvii. *Mudstone Facies:*

Mudstone is grey in color, interbedded with siltstone and sandstone. Exhibits nodular structure, conchoidal fracture, load structure. It is found in Unit- D and Unit- G (see fig-17).

xviii. *Claystone Facies:*

Bluish grey color, clay size particle dominant, argillaceous cementing material, moderately hard and compact interbedded with mudstone, sandstone. This facies widely studied in unit-G and unit –D (see fig-17).

Figure 17: Claystone (right) and Mudstone (left) as observed Dupigaon section and Sari River section respectively.

xix. *Conglomerate Facies:*

It is dark brown to reddish brown color, very hard highly weathered and highly oxidized. This conglomerate bed is extra formational because the source area is so far from the depositional basin and it indicates an unconformity.

Figure 18 Conglomerate as observed in Sripur Tea Garden section.

4.2 Grain Size Analysis

Grain size analysis includes the mechanical analysis and mineralogical study of the sediments. The purpose of this work is to examine the exposed sediments and to determine their lithological characteristics. In laboratory we have worked on grain size analysis and heavy mineral separation and identification.

Grain size is a fundamental attribute of siliciclastic sedimentary rocks and thus one of the important descriptive properties of such rocks. Sedimentologists are particularly concerned with three aspects of particle size:

1. Techniques for measuring grain size and expressing it in terms of some type of grain size of grade scale.
2. Presenting them in graphical or statistical form so they can be easily analyzed.
3. The genetic significance of these data.

Several methods use for the grain size analysis of sedimentary rocks such as settling velocity, microscopic method, sieving method etc. The scope of each of these methods is, however, limited by factors like the degree of consolidation of the sediments, nature and purpose of investigation etc. We use the sieving method to analyze the grain size. It is the common method for laboratory analysis.

The following parameters were calculated in the laboratory-

1. Cumulative curve:

Cumulative curve has been drawn on the logarithmic graph paper by plotting the cumulative weight percent retained as ordinate and corresponding grade size as abscissa.

2. Histogram:

It is a block diagram which gives the percentage of grains in the grade size present in the sediment. It is constructed by plotting the grade size in the abscissa and the percent weight retained in the ordinate.

Grain size parameter:

Different statistical parameters were calculated from cumulative curve, according to Folk and ward methods (1968). The parameters are:

a. Graphic means:

An approximation of the arithmetic mean can be arrived by picking selected percentile values from cumulative curve, and averaging these values, by using the following formula:

Equation 1: Equation for determining Graphic Mean

$$M = \frac{\phi 16 + \phi 50 + \phi 84}{3}$$

Table 2: M Values

Values from	To	Equal
- ∞	-1ϕ	gravel
-1	0ϕ	very coarse sand
+0	+1ϕ	coarse sand
+1	+2ϕ	medium sand
+2	+3ϕ	fine sand
+3	+4ϕ	very fine sand
+4	+8ϕ	silt
+8	∞ ϕ	clay

b. Graphic standard deviation (Sorting):

Generally sorting means dispersion; character, shape, facies, and size are differentiated from a heterogeneous mixture. The mathematical expression of sorting is the standard deviation. Sorting can be estimated in the field or laboratory by use to hand lenses or microscope and reference to visual estimation chart that is given is given below:

Equation 2: Equation for determining Graphic Standard Deviation

$$D = \frac{\phi 84 - \phi 16}{4} + \frac{\phi 95 - \phi 5}{6.6}$$

Table 3: D values

Values from	To	Equal
0.00	0.35ϕ	Very well sorted
0.35	0.50ϕ	Well sorted
0.50	0.71ϕ	Moderately well sorted
0.71	1.00ϕ	Moderately sorted
1.00	2.00ϕ	Poorly sorted
2.00	4.00ϕ	Very poorly sorted
4.00	∞ ϕ	Extremely poorly sorted

c. The symmetry of distribution (Skewness):

It is determined whether the coarser material exceeds the fine material or fine material exceeds coarser materials. Skewness reflects sorting in the 'Tails' of grain size population, populations with a tail of excess fine particles are said to be positively skewed or fine skewed, it means skewed towards positive φ values. Populations with a tail of excess coarse particles are negatively skewed or coarse skewed. It means skewed towards negative φ values. The visual estimation chart of Skewness is given below:

Equation 3: Equation for determining the Skewness.

$$S = \frac{\phi 84 + \phi 16 - 2(\phi 50)}{2(\phi 84 - \phi 16)} + \frac{\phi 95 + \phi 5 - 2(\phi 50)}{2(\phi 95 - \phi 5)}$$

Table 4: S Values

Values from	To	Mathematically	Graphically Skewed to the
+1.00	+0.30	Strongly positive skewed	Very fine Skewed
+0.30	+0.10	Positive skewed	Fine Skewed
+0.10	- 0.10	Near symmetrical	Near symmetrical

- 0.10	- 0.30	Negative skewed	Coarse Skewed
- 0.30	- 1.00	Strongly negative skewed	Very coarse Skewed

d. Kurtosis (Peakedness of distribution):

Statistically kurtosis measures the ratio between the sorting in the tails (cumulative curve has coarser and finer tails or ends) and the sorting in the central position of the curve. It indicates the behavior of the environment.

If the central portion is better sorted than the tails, the frequency curve is called leptokurtic. If the tails are better sorted than the central portion, the curve is said to flat peaked or Platykurtic.

As in the case for mean and standard deviation, the grain size units that are used affect Skewness and kurtosis. The visual estimation chart of Kurtosis is given below:

Equation 4: Equation for determining Kurtosis.

$$K = \frac{\phi 95 - \phi 5}{2.44\,(\phi 75 - \phi 25)}$$

Table 5: K Values

Values from	To	Equal
0.41	0.67	very platykurtic
0.67	0.90	platykurtic
0.90	1.11	mesokurtic
1.11	1.50	leptokurtic
1.50	3.00	very leptokurtic
3.00	∞	extremely leptokurtic

Calculations in the Laboratory:

We collected six different samples for grain size analysis in our fieldwork. The locations from which these six different sample of different rock types were collected are mentioned in the table below:

Table 6: Description of different samples used for laboratory analysis.

Sample No.	Section Name	Rock Type	Weight Taken (gm)	Weight Retained (gm)
1	Dupigaon	Variegated Sandstone	100	99.8
2	Dupigaon		100	99.75
3	Sari River	Yellowish Brown Sandstone	100	99.63
4	Sari River	Tipam Sandstone	100	99.85
5	Sari River	Cross-bedded Sandstone	100	99.85
6	Tamabil	Pink Sandstone	100	99.92

The results of the grain size analysis of the aforementioned samples are described as following:

Sample No	**Graphic Mean**	**Standard Deviation**	**Skewness**	**Kurtosis**
1	Fine Sand	Moderately Well Sorted	Positive Skewed	Very Leptokurtic
2	Medium Sand	Poorly sorted	Positive Skewed	Mesokurtic
3	Fine Sand	Poorly sorted	Strongly Positive skewed	Platykurtic
4	Fine Sand	Moderately Sorted	Symmetrical	Very Leptokurtic
5	Fine Sand	Very poorly sorted	Near symmetrical	Leptokurtic
6	Fine Sand	Moderately Sorted	Negative skewed	Very Leptokurtic

Table 7: Results of Laboratory Analysis.

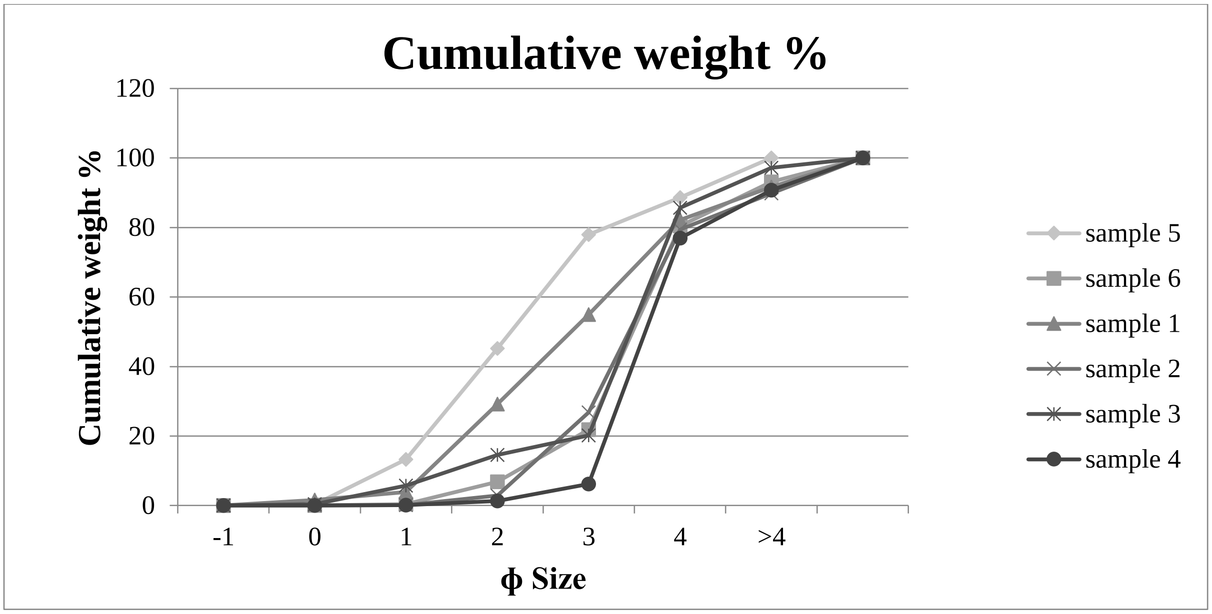


Figure 19 Cumulative Weight (%) vs Phi size

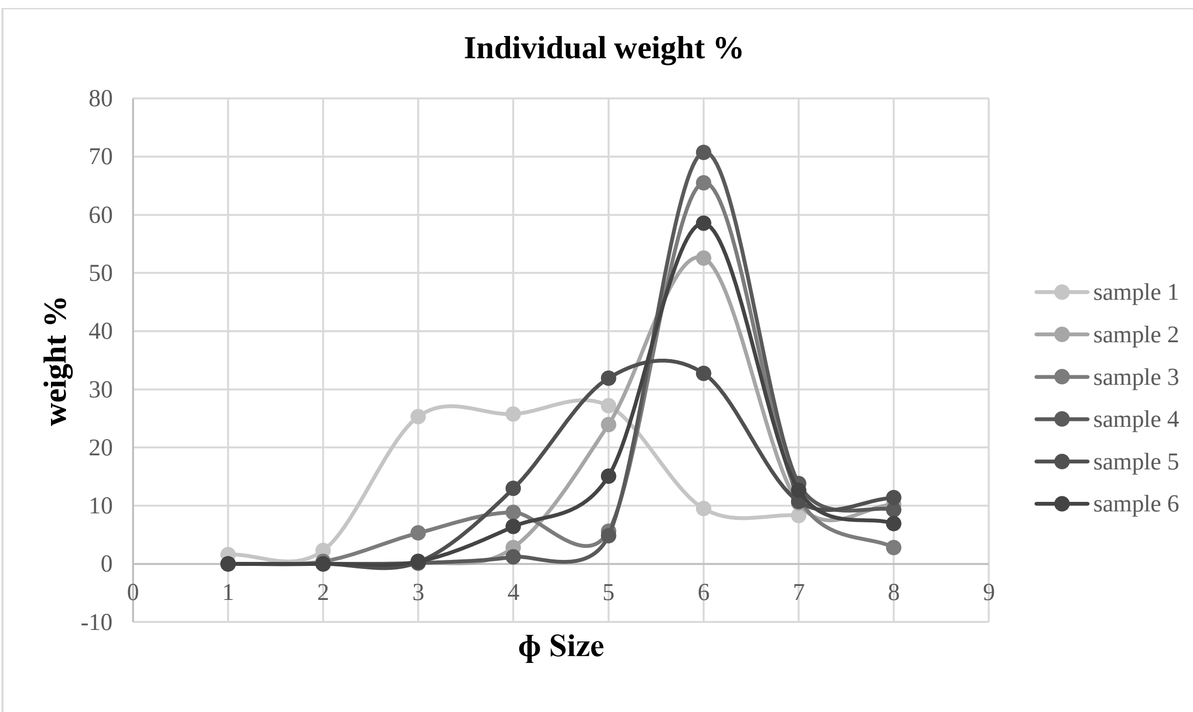


Figure 20 Individual Weight (%) vs Phi size

Chapter 5 Stratigraphy and Correlation

Stratigraphy is a branch of geology concerned with the study of rock layers (strata) and layering (stratification). A common goal of stratigraphic studies is the subdivision of a sequence of rock strata into mapable units, determining the time relationships that are involved and correlating units of the sequence, or the entire sequence, with rock strata elsewhere.

Stratigraphy of the Bengal Basin is not so easy to establish because of the lack of continuous rock exposure and for the presence of thick alluvial cover, dense vegetation and due to its complex tectonic structure (Muminulllah, 1978). As a result, the stratigraphy of the Bengal Basin has been correlated with the stratigraphy of the Assam region (Evans, 1932) which has different tectonic history.

We investigated the Jaintiapur area within the Sylhet district which occupies exposures of a continuous stratigraphy of the Sylhet Trough and consequently, it is relatively easier to determine stratigraphy at Jaintiapur. The established stratigraphy was later correlated with the stratigraphy if the Assam region.

5.1 Stratigraphy of the Investigated Area

Based on our field observations, eight litho-stratigraphic units were found. These units from Oldest to Youngest are Unit-A (Fossiliferous Limestone), Unit-B (Dark Black Shale), Unit-C (Pinkish Sandstone), Unit-D (Silty Shale), Unit-E (Alternation of Sandstone and Shale), Unit-F (Yellowish Brown Sandstone), Unit-G (Mottled Clay), and Unit-H (Variegated Colored Sandstone). In some cases contact between two units was distinguished.

Following is the description of the major rock types of these units and of the depositional environment.

Relative Age	Rock Unit	Formation	Lithology	Thickness (m)	Depositional Environment
Youngest	Unit-H	Variegated Colored Sandstone	Yellowish, pinkish and grey in color, medium to coarse grained, arenaceous and ferruginous cementing materials, highly permeable and loosely compacted. The grains are sub-rounded to rounded and moderate to poorly-sorted.	1492.25	Fluvial
	Unit-G	Mottled Clay	Bluish grey in color, clay size particle, medium to high plasticity with high content of organic matter with massive sedimentary structure.	260.35	Fluvial (Overbank)
			Unconformity		
	Unit-F	Yellowish Brown Sandstone	Alternation of grey colored shale that contains clay sized particles with argillaceous cementing material and greyish brown sandstone which is fine to medium grained with moderate compactness. Parallel lamination with interbedded shale, wavy, flaser and lenticular bedding, also nodular, flame, and hummocky structures were also found.	2794	Fluvial
	Unit-E	Alternation of Sandstone and Shale	Alternation of grey colored shale that contains clay sized particles with argillaceous cementing material and greyish brown sandstone which is fine to medium grained with moderate compactness. Parallel lamination with interbedded shale, wavy, flaser and lenticular bedding, also nodular, flame, and hummocky structures were also found.	2603.5	Deltaic
	Unit-D	Silty Shale	Grey in color, containing mostly clay sized particles and clay minerals, argillaceous cementing material. Lenticular structure with small-scale micro cross lamination, parallel lamination, ball and pillow structure, iron incrustation, and lesigan structures were also found.	2063.75	Shallow Marine
			Unconformity		
	Unit-C	Pinkish Sandstone	Pink in color, fine grained, high porosity and permeability, ferruginous cementing material. Contains occasional grey colored interbedded shale that is fissile in nature. Sedimentary structures include planar cross lamination, trough cross bedding, presence of carbonaceous matter, iron incrustation, and burrows	Unidentified	Deltaic to Fluvial
	Unit-B	Dark Grey Shale	Dark black in color with abundant clay sized particles. This rock unit contains argillaceous cementing materials and is fissile in nature. Presence of Pelecypod was found.	76.2	Shallow Marine
			Unconformity		
Oldest	Unit-A	Fossiliferous Limestone	Greyish brown in color, massive, poorly porous, very hard and compact. These limestone give effervescence with cold dilute HCL. It is non-clastic and highly fossiliferous. The Nummulitic fossils are identified in naked eyes with concentric appearance which is classified as macrofossil.	254	Shallow Marine

Table 8: Stratigraphic table of the investigated area.

5.2 Depositional Environment of the Stratigraphic Area

Depositional environment of the investigated area is determined mainly on the basis of lithology, sedimentary structure and association of different lithofacies.

Unit-A (Fossiliferous Limestone): Greyish brown in color, massive, very hard and compact. These limestone give effervescence with cold dilute HCL. The Nummulitic fossils are identified in naked eyes with concentric appearance which is classified as macrofossil. The presence of Nummulitic index fossils indicates warm, humid climate condition and shallow marine depositional environment of Eocene time.

Unit-B (Dark black shale): This rock unit is highly organic material rich, presence of palecepod with parallel lamination sedimentary structure. Dominantly shale and silty shale present indicate the shallow marine environment.

Unit-C (Pinkish sandstone): This rock unit comprises massive fine grain sandstone with parallel lamination, cross lamination. Micro cross laminated sandstone facies indicate deltaic to fluvial environment.

Unit-D (Silty shale): This rock unit grey in color with presence of parallel lamination ,flaser bedding, lenticular bedding with micro cross lamination and characterized by flaser bedded sandstone facies , micro cross laminated facies , siltstone facies, mudstone facies, claystone facies. The greater presence of clay, mud and silt indicate shallow marine environment.

Unit-E (Alternation of sandstone and shale): This rock unit comprises with parallel lamination with inter bedded shale, flaser bedding , lenticular bedding with micro cross lamination , wavy bedding, hummocky cross stratification and bipolarity and characterized by micro cross laminated sandstone facies ,flaser bedded sandstone facies which indicate tide dominated deltaic condition.

Unit-F (Yellowish brown sandstone): this unit characterized by yellowish brown color contain thin streak of coal, mud crust and presence of clay gall. Low angle cross bedding, planner cross lamination, trough cross bedding, large scale cross bedding, channel lag deposit. The sedimentary structures and high content of clay gall indicate fluvial depositional environment.

Unit -G (Mottled clay): Bluish grey in color with massive structure which is entirely composed of clay sized particles .This clay accumulated in sub areal marshy condition as swampy, lacustrine and fluvial over bank deposit.

Unit – H (Variegated color sandstone): This rock unit characterized by pinkish, brownish, yellowish color, loosely compact enormous presence of pebble but less clay gall. Large scale cross bedding, trough cross bedding, flute marks, wood fragment, plant fossils present. Claystone, mudstone, siltstone facies are associated. All the evidence found in this rock unit indicate fluvial depositional environment.

The sedimentary structures by which the depositional environments of these stratigraphic formations were determined are as follows:


Figure 21 Flaser (left) and Lenticular (right) bedding as observed in Nayagang section.

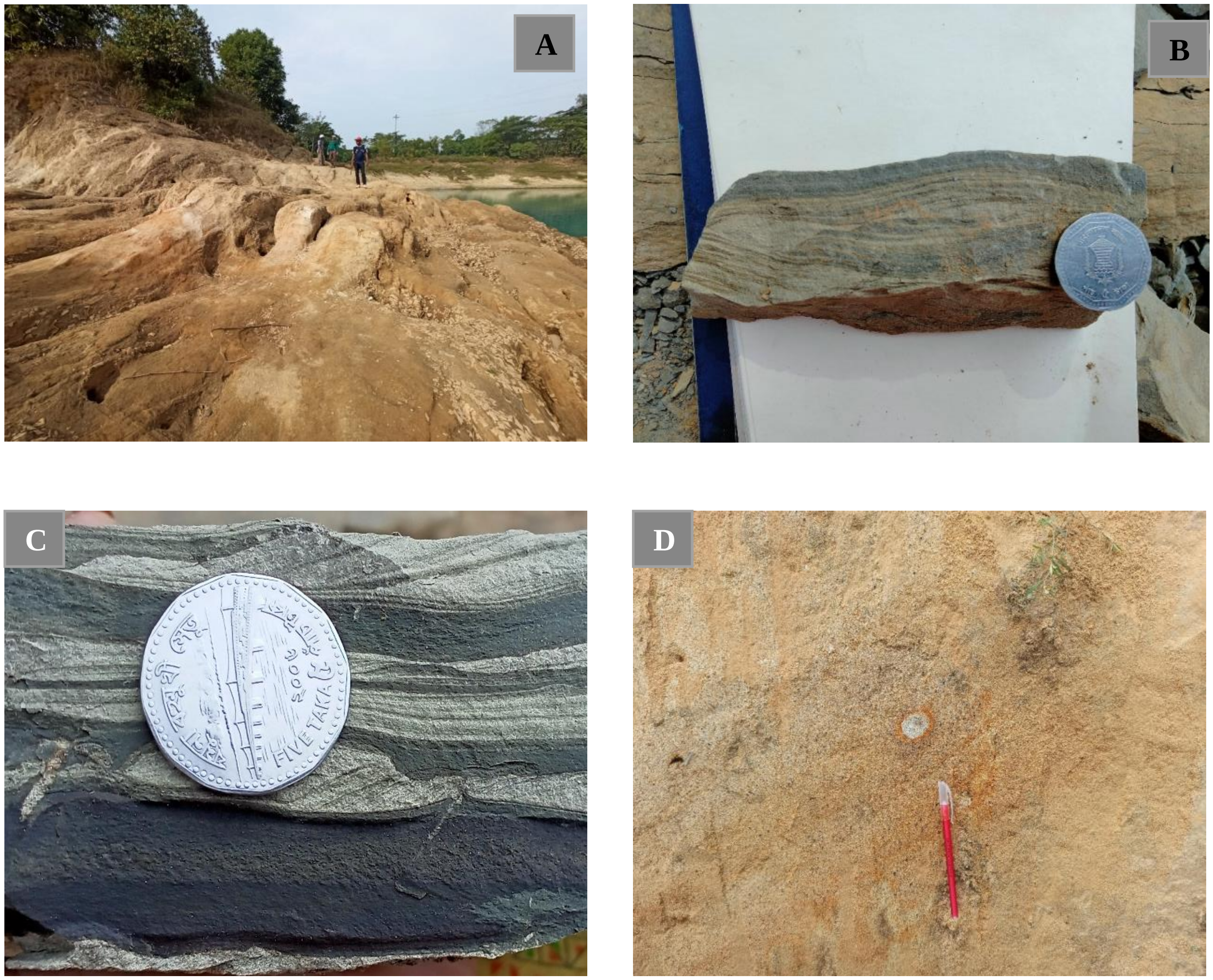


Figure 22 Trough Cross bedding (A), Hummocky structure (B), Wavy Bedding (C), and Clay galls (D) as observed in the Sari river section.

Figure 23 Flute Marks (left) and Burrows (right) as observed in Dupigaon and Sripur Tea Garden sections respectively.

5.3 Correlation with Regional Stratigraphy

Study area			Stratigraphy of the Bengal Basin (after Alam et al., 2003, Johnson and Alam 1991, Najman et al., 2008, Reimann 1993, Shamsuddin and Abdullah 1997)			Dep. Env.	Probable Age
Rock Unit	Major Rock Types	Lithology	Group	Formation	Lithology		
Unit - H	Variegated Colored Sandstone	Yellowish, pinkish and grey in color, medium to coarse grained, arenaceous and ferruginous cementing materials, highly permeable and loosely compacted. The grains are sub-rounded to rounded and moderate to poorly-sorted. Enormous presence of pebbles was observed.	Dupi Tila	Dupi Tila	Variegated Colored Sandstone	Fluvial	Pleistocene to Late Pliocene
Unit - G	Mottled Clay	Bluish grey in color, clay size particle, medium to high plasticity with high content of organic matter, massive sedimentary structure.	Tipam	Girujan Clay	Mottled Clay	Fluvial (Over bank)	Late to Early Pliocene
Unit - F	Yellowish Brown Sandstone	Yellowish brown in color, fine to medium grain size, cementing material is ferruginous, highly porous and permeable, moderately hard and compacted. The grains are sub-angular to sub-rounded. Observed sedimentary structures include large-scale trough cross bedding, paraller cross bedding, presence of clay gall, and very thin layer of petrified wood and streak of coal.		Tipam	Yellowish Sandstone	Fluvial	
Unit - E	Alternation of Sandstone and Shale	Grey colored shale, containing clay sized particles, argillaceous cementing material. Greyish brown sandstone, fine to medium grained, moderately compacted, ferruginous cementing material. Parallel lamination with interbedded shale, wavy, flaser and lenticular bedding, also nodular, flame, and hummocky structures were also found.	Surma	Bokabil	Sandy Shale	Deltaic	Late Miocene

Unit - D	Silty Shale	Grey in color, containing mostly clay sized particles and clay minerals, argillaceous cementing material. Lenticular structure with small-scale micro cross lamination, parallel lamination, ball and pillow structure, iron incrustation, and lesigan structures were also found. In addition, calcareous sandstone band was also observed.		Bhuban	Silty Shale	Shallow Marine	Middle to Early miocene
Unit - C	Pinkish Sandstone	Pink in color, fine grained, highly permeable, ferruginous cementing material. Contains occasional interbedded shale which is grey colored, and consists of clay sized particles, argillaceous cementing material, occasionally fissile in nature. Sedimentary structures include planar cross lamination, trough cross bedding, presence of carbonaceous matter, iron incrustation, and burrows.	Barail		Pinkish Sandstone	Deltaic to Fluvial	
Unit -B	Dark Grey Shale	Dark black in color with abundant clay sized particles. This rock unit contains argillaceous cementing materials and is fissile in nature. Presence of Pelecypod was found.	Jaintia	Kopili Shale	Greyish Black Shale	Shallow Marine	Middle to Early Eocene
Unit - A	Fossiliferous Limestone	Greyish brown in color, massive, poorly porous, very hard and compact. These limestone give effervescence with cold dilute HCL. It is non-clastic and highly fossiliferous. The Nummulitic fossils are identified in naked eyes with concentric appearance which is classified as macrofossil.		Sylhet Limestone	Fossiliferous Limestone	Shallow Marine	

Table 9: Correlation of the stratigphy of the studied area with the Stratigraphy of Bengal Basin.

Chapter 6 Description of Structural Analysis

The investigated area and adjoining area lie within the Sylhet trough of Bengal Foredeep. Sylhet trough is situated south of Shillong Massif and corresponds with vast low land of Surma basin. The northern limit of this subsiding trough is bounded by Dauki fault. Faulting along the Shillong shelf zone coincided with rapid subsidence of Surma basin is during Miocene and later time. The basin has been encountered two short periods of erosion and non-deposition. One is due to the time of uplift and folding in the east and continued subsidence in west at the end of Oligocene; the other is due to the uplift of Shillong plateau accompanied by faulting in late Miocene and later time.

The area is a tectonically complex province and is controlled by a very complex system of faults, popularly known as the Dauki Fault System trending E-W along the border of the Shillong Massif (Evans, 1964). The dominant structures of the study area are fold, fault, unconformity, and joint.

6.1 Major Structure

6.1.1 Fault

Jaintiapur and the adjacent areas form an east-west narrow strip along a major thrust, called Dauki Fault (Murthy et al. 1969). The northern part of this fault was uplifted with the rising Shillong Massif, the southern has been down-faulted and concealed beneath a thick clastic sequence of Plio-Pliestocene age (Reimann, 1993). Hiller (1988) could prove that the maximum through of the fault system amount to as much as 18 km in the eastern half, whereas the throw decrease significantly towards the west. The development of faults of localized nature in the area is possibly synchronous with the major Dauki Fault. The faults are step-like in nature and are associated with the major Dauki Fault.

The Dauki Fault is exposed along the southern margin of the Shillong plateau for about 170 km from Jadukata River and the trend of the fault as observed from Jaflong is NE-SW. Evidences that support the existence of the Dauki Fault as observed from Jaflong are as follows:

I. Sudden topographical change and high relief difference was observed within a few hundreds of meters. The difference between altitude in Bangladesh and India is a major evidence for the existence of this fault. According to Evans (1964), the amount of structural relief on both sides of the Dauki Fault ranges up to 13000 meters.
II. Existence of Dauki Fault is also evidenced by the presence of a drainage basin called the Dauki River.
III. Faulting is also evidenced by the presence of fault breccias found within the Sylhet Limestone formation.

6.1.2 Lineaments

Lineament can be defined as a linear feature in a landscape like a visible line or a long crack or a long visible dent. Lineaments are basically an expression of an underlying fault. They might occur as a fault aligned valley, a straight coast line, or as a series of fault, or fold aligned hills, or a combination of all the features. The occurrence of a lineament can be captured in a satellite photograph.

Based on our observation, two major lineaments were identified and these are named L1 and L2. L1 was presumed to exist between Unit-G and Unit-E. The trending of L1 is congruent with the trending of the surrounding rock formations. Evidences for the existence of L1 are as follows:

I. Repetition of Unit-E.

II. Steepness of dip.

The other lineament, namely L2 was observed in Unit-H. Evidences that indicate the presence of L2 are as follows:

I. Overturned trough-cross bed was observed in Unit-H in Dupigaon section.

II. Anomalous dip was detected. General dipping of the strata is SW, but here NE and E dipping was observed.

III. Presence of Flute Marks also indicated the existence of a fault.

6.2 Minor Structures

6.2.1 Minor Fold

We observed a minor fold in Tamabil Road Cut Section which was probably developed due to the regional Dauki Fault.

Figure 24 Minor fold observed in Tamabil Road Cut Section.

6.2.2 Joints

As joints are typically associated structure of faults, the joints observed in our investigated area can be assumed to be the result of Dauki fault movement. Moreover if we review the regional setting of the area it can be seen that multidirectional forces with variable intensities were responsible for the development of the investigated area. As a consequence, joints having different orientation and extension are scattered available throughout the investigated area. The description and location of some remarkable joints are mentioned below:

I. Minor scale Strike and Dip joints were observed in the Sylhet Limestone near the Dauki River. Based on our observations, Dip joints are larger in length than the Strike Joints. The Dip length of the Dip joints ranges from 2-3 meters and the spacing ranges from 4-5 centimeters. On the other hand, the length of the Strike joints ranges from 15-20 centimeters and the spacing ranges from 6-8 centimeters.

II. Highly jointed Barail Sandstone is observed along the Sripur road-cut section.

III. Some Oblique joints were observed in Tamabil Road Cut section


Figure 25 Oblique Joint (left) and Strike and Dip Joints (right) observed in the studied area.

Figure 26 Angular Unconformity observed in Dauki River Section.Figure 27 Oblique Joint (left) and Strike and Dip Joints (right) observed in the studied area.

6.2.3 Non-depositional Unconformity/ Disconformity

A major unconformity exists between Barail and Surma group near the eastern bank of Nayagang stream (in the north of Jaintiapur) at Latitude 250 08/ 24.4// N and Longitude 920 7/ 18.1// E. It is represented by a thin band of lateritic conglomerate, as observed in the field. The band of laterite is red to dark brown colored and is composed of pebbles, cobbles, granules and other ill-sorted materials. The laterite might have formed by the hardening of the weathering products of the Barail group of rocks (hematite cemented sandstone) during prolong exposure before deposition of the Bhuban sediments. According to the field investigation it can be categorized as disconformity. This is because the laterite band was continuous along the contact and parallel to the strike of both formations.

Figure 28 Laterite Bed as observed in Nayagang Section.

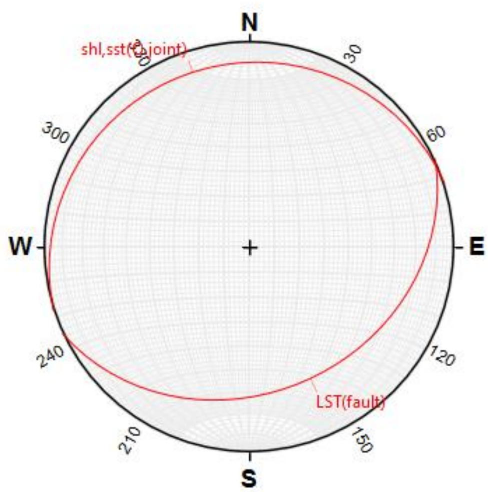
6.2.4 Angular Unconformity

The Gravel bed observed in Tamabil Road-Cut section makes an unconformity with the Barail Group of sediments. The underlying beds are inclined and the overlying gravel beds are laid horizontally. This suggests that the observed unconformity might be an Angular Unconformity.

Figure 29 Angular Unconformity observed in Dauki River Section.

6.3 Stereonet Analysis

By using Stereonet data, it is possible to interpret the overall structural sequence of the studied area.



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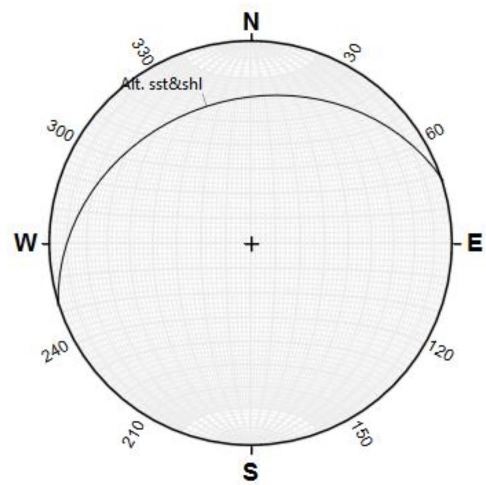

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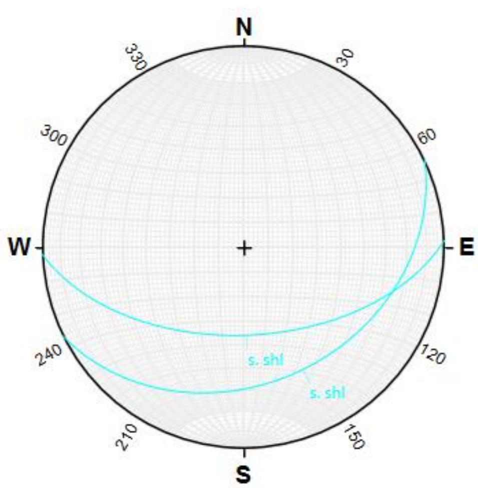
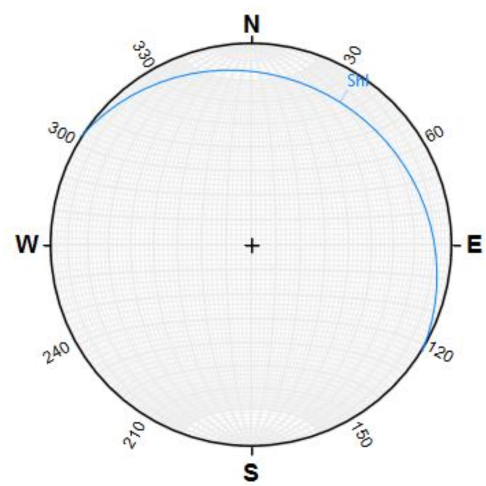
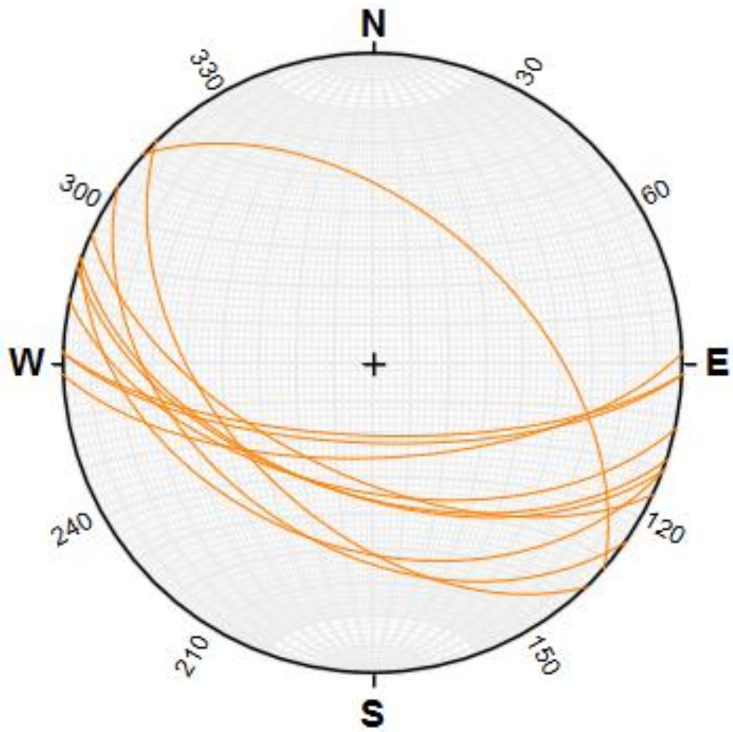


C



D



E

Figure 30 Stereonets of (A) Dauki-Tamabil Road cut section, (B) Jaflong - Tamabil Road Cut section, (C) Nayagang-Kamalabari section, (D) Sripur Tea Garden section, and (E) Sari River and Dupigaon section.

Chapter 7 Geologic History

Jaintiapur area lies in between two contrasting structural set ups, the uplifting Shillong Massif in the north and the subsiding Surma basin in the south, It is bounded by the Khasi-Jaintia hills and Shillong Massif in the North, Goyain trough in the south, Atgram anticline structure in the east. The area forms a narrow east-west elongated strip and is characterized by intermittent swamps between the hills.

The Surma basin, a sub basin of the Bengal basin is bounded to the north by the Shillong Plateau, to the east and southeast by the Chittagong-Tripura fold belt of the Indo-Burman ranges, and to the west by the Indian Shield platform. It is open to the main part of the Bengal basin to the south and southwest.

In the field survey at Jaintiapur and its surrounding areas, the rock units are determined and divided into eight formations based on their petrologic characteristics. These are:

Unit A: Limestone Formation: Presence of Limestone suggests that it was deposited in shallow to open marine environment at middle Eocene age.

Unit B: Black Shale Formation: Shale is dark colored and contains organic matter and a huge number of fossils. Black shale was deposited in the open marine, shallow marine or shelf environment at Eocene age.

Unit C: Pinkish Sandstone Formation: Sandstone with thick bedding and locally cross lamination indicates deposition in a high energy condition of fluvial environment of tropical temperate climate. Shale contains flaser bedding with calcareous sandstone bent that indicates tidal environments. Based on these observationas, it can be said that pinkish sandstone formation was deposited at deltaic to fluvial environment at Oligocene age.

Unit D: Silty Shale Formation: Silty shale indicates shallow marine environment at Early Middle Miocene to Late Miocene.

Unit E: Sandstone Shale Alternation Formation: This formation contains sandstone, shale with hummocky cross stratification, micro cross lamination, wavy bedding, bipolarity which indicates that this formation was deposited under tide dominated deltaic condition at Late Miocene.

Unit F: Yellowish Brown Sandstone Formation: Presence of cross bedding and coal suggests that it was deposited in fluvial (braided) environment of tropical temperate climate at Early Pliocene age.

Unit G. Mottled Clay Formation: This clay was accumulated in sub aerial marshy condition as swampy, lacustrine and fluvial over bank deposit at Early to Late Pliocene.

Unit H: Variegated Color Sandstone Formation: Trough cross bedding with coal matter suggest that variegated colored sandstone was deposited in fluvial (meandering) environment of tropical temperate climate at Pleistocene age.

The major active tectonic structure in our study area is the Dauki Fault. The Dauki fault which passes along the southem margin of the Shillong Plateau is an E-W trending reverse fault inclined to the north. The plate boundary mega-thrust between the Indian and the Burman plate around Bangladesh is divided into the Tripura and the Arakan segments. The flow direction of the Dauki River is another indicator to the presence of a major fault. Spread between the block faulted Paleogene sediments of the Northern Foreland Shelf and the block faulted Piedmont deposits of Plio-Pleistocene age of the Garo Hills, the Dauki Fault is a structural unit of considerable regional importance.

Unit A is the oldest rock unit and Unit H is the youngest stratigraphic formation. According to the law of superposition and Walthers law, we would have found these strata in sequence. But we observed repetition of strata. As we know the area is tectonically active due to its compressional setting and the impacts of the active Dauki fault might be the reasons behind this repetition of strata.

Chapter 8 Economic Geology

Economic geology is concerned with earth materials that can be used for economic and/or industrial purposes. These materials include precious and base metals, nonmetallic minerals, construction-grade petroleum minerals, coal, and water. The term commonly refers to metallic mineral deposits and mineral resources. The techniques employed by other earth science disciplines (such as geochemistry, mineralogy, geophysics, and structural geology) might all be used to understand, describe, and exploit an ore deposit.

Source rocks include the sylhet and kopili formation shales (correlated with unit B), Barail group (Jenum Shale) coals and shales (correlated with unit-C), and in the south the surma group shales. Total organic content is generally low, averaging from 0.5 to 1.8 percent; it is as high as 9 percent in the Barail coal shales.

Reservoir rock in our studied area include Unit-D (Silty Shale) correlated with lower Surma group named Bhuban) and Unit-E (Alteration of Sandstone and Shale) correlated with Bokabil may be work as reservoir rock of petroleum.

Jaintiapur and its adjacent areas are well known for some economically workable mineral deposits such as boulder and gravel bed deposit, sand of Sari River, limestone deposit etc.

They are described below:

I. **Boulder bed:** Boulder excavation from the Dauki River is one of the major income sources of the locality. Boulder, pebbles and gravels of Dauki river section are also important because it is widely used for building materials. But at present collection of boulders is hazardous to environment due to excessive collection rather than its sustainable use. Boulders are also found in more or less every section of our investigated area.

II. **Limestone:** Limestone is one of the best raw materials used as cement and building constructive materials. The reserve of limestone of our investigated area is adequate to meet the demand of local needs is of comparable good quality. It is extensively used as mosaic materials.

III. **Sand:** Sand is abundantly found in our studied area, the channel sand deposits, i.e. Streams of Dauki, Nayagang ard Sari are economically important for their uses in construction purposes. Sands that are free from iron content are good for construction. Some sands deposit of iron content could be used for glass sand.

IV. **Conglomerates**: Conglomerates are found in Dauki River section. The main use of the Conglomerate is making steps of ponds and small culverts.

V. **Calcareous band:** The calcareous sandstone band found in the investigated areas which are very hard can be economically very important if utilized in proper ways. The thickness is about 10cm to 25 cm. This is very hard and supplied in the different parts of the country by the local people. This is mainly used for road and building constructions purpose. These are also used for railway ballast, bridges, culverts, dams, and for other purposes.

VI. **Shale and clay:** These deposits are used for manufacturing the goods of ceramic in ceramic industry. They are also used extensively for the manufacturing of bricks by indigenous methods.

Conclusion

The investigated Jaintia and adjoining areas within the latitude of 92°0' to 92°15'N and the longitude of to 25°10' E is covers from east-west side by a narrow strip along a major thrust called Dauki fault. Tamabil seems to be an anticline but can be better explained by roll against the major Dauki fault, the compressional forces are responsible for making the area tectonically disturbed. These did not help develop an anticline structure. The reversal of dip was caused due to roll over against the Dauki fault. The exposed rock in the investigated area, on the basis of lithology the sedimentary sequence is divided into eight unit namely-

Unit-H (Variegated Sandstone), is correlated with Dupi Tila and represents fluvial depositional environment. Unit-G (Mottled Clay), is correlated with Girujan clay of Tipam group and represents overbank depositional environment. Unit-F (Yellowish Brown Sandston is correlated with Tipam sandstone and represents fluvial depositional environment. Unit-E (Alteration of Sandstone and Shale) is correlated with Bokabil formation and represents tidal depositional environment. Unit-F (Silty Shale) is correlated with Lower Surma group and represents shallow marine depositional environment. Unit-C (Pinkish Sandstone) is correlated with Barail group and represents deltaic to fluvial depositional environment. Unit-B (Black Shale) is correlated with Kopili formation of Jaintia group and represents shallow marine environments. Unit -A (Limestone) is correlated with Sylhet limestone of Jaintia group and represents shallow marine depositional environment.

Major tectonic structures found on the studied area includes a monoclonal fold, Dauki fault, and lineaments. On the other hand, minor structures include minor fault, fracture, joints (oblique joint, strike joint, and dip joint), and unconformity. Sudden lithological changes and repetition of strata have also been observed.

Based on lithological observation and correlation it can be said that Unit-B (Black Shale) might acts as a source rock, while Unit-D (Silty Shale) and Unit-E (Alternation of Sandstone and Shale) might act as a reservoir rock. Lastly, the studied area is economically much significant due to the presence of economic deposits such as boulder bed, limestone, sandstone, claystone etc.

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Appendix