Abstract

The investigated area, known as Sitapahar anticline, is about 70 km (N-S) long and 12 km (E-W) wide and covers about 550 sq. km of Rangamati district. It lies in the middle zone of CTFB, with NNW-SSE trending, characterized by more compressed structures frequently associated with faults. It has become possible to appreciate the complexity of the area as well as the stratigraphy and the structure of the associated areas by the field work operated at Sitapahar in Rangamati which lies in the south eastern part of Bangladesh.

The investigated area is characterized by several types of rocks that are exposed along both sides of the road. Units found from the observation in the area are, from Oldest to Youngest, Nodular Bluish Gray Shale (Unit A), Alternation of Sandstone and Shale (Unit B), Brownish Sandstone (Unit C), and Yellowish Brown Sandstone (Unit D). 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 Bhubon, Bokabil, Tipam and Dupi Tila formation respectively.

Lithology, structural analysis, and petrological studies prove that the investigated area were deposited from Shallow Marine to Continental fluviatile environment where sedimentation took place by strong current.

Even though the investigated area has small economic value, it is considered as highly prospective for hydrocarbon exploration. Despite the abundance deposition of Sandstone and Shale in the area, there’s very little implementation of these rocks because of its loose compactness.

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

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SUMON KANTI DAS

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Chapter-1
Introduction

“Geology is the major concept of earth science and the whole world is a laboratory for a geologist”. Geology is best studied in the field and for this reason, field work is a vital part for the extensive knowledge of geology. Sitapahar structure, situated in Rangamati district and lying in the southeastern Bangladesh, is one of the best practically observable areas in our country due to the abundance of exposures. The hilly part of Rangamati district provides good exposures of rock needed for the investigation. A huge thickness of clastic sedimentary rock is well exposed which offers an excellent opportunity to carry out a field work and for this purpose, we, the students of 3rd year (Hon’s) carried out a geological fieldwork with the help of the Department of Geological Sciences, Jahangirnagar University.

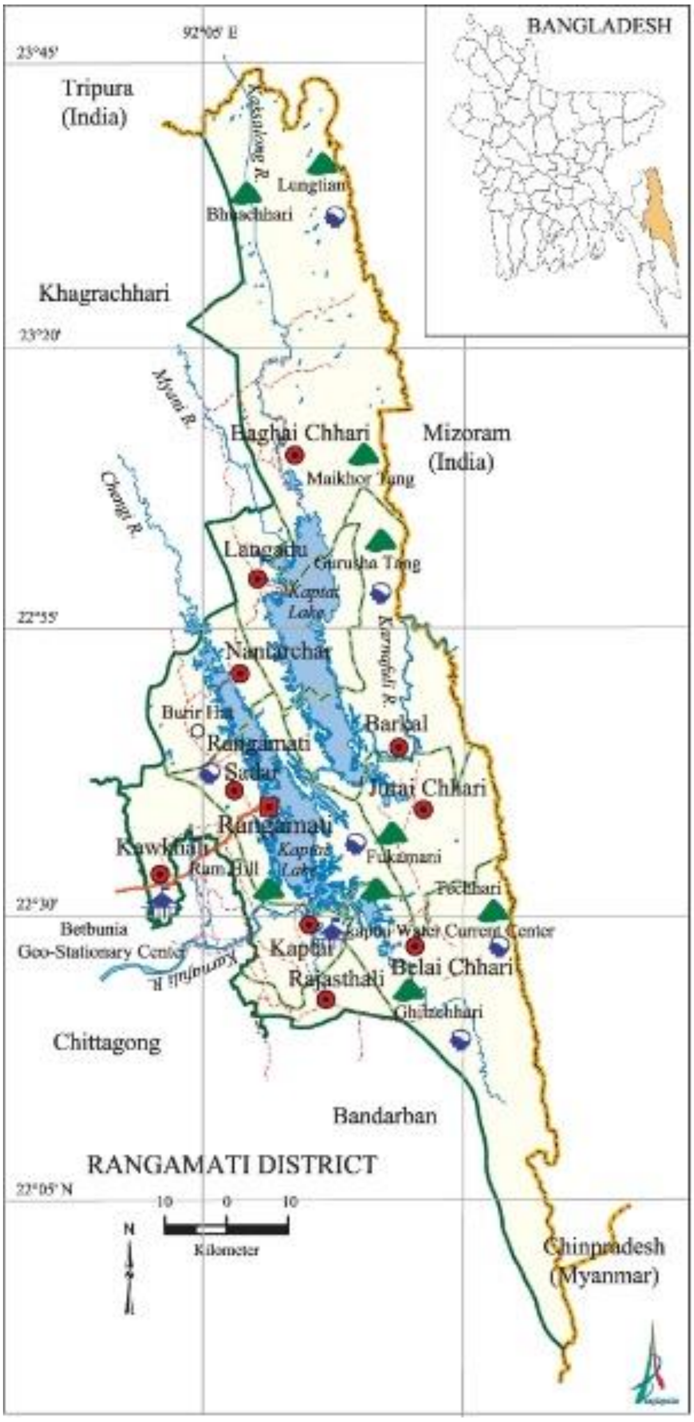
The extensive fieldwork had been conducted at the Ghagra- Rangamati road cut section in Rangamati District. The aim of our expedition was to investigate a geological folded structure, known as the Sitapahar Anticline, which is an asymmetric anticline and situated in the investigated area. Moreover, the western flank of the anticline is steeper than the eastern flank and the anticline is trending towards NNW-SSE direction.

The report deals with the lithology, structure, stratigraphy, and economic importance of the observed area, that are being described based on the field data, grain size analysis data and analysis of the collected samples from the investigated area.

1.1 Location and Extent

Our investigated area lies at Sitapahar in Rangamati district; at a distance of about 250 km southeast of Dhaka city, and 70 km southeast of Chittagong city and its adjacent areas along the northern part of the Sitapahar hill range. Rangmati district is bounded by Tripura state of India on the North, Arakan (Myanmar) on the South, Mizoram state of India and Chin

Pradesh of Myanmar, and Chittagong on the west. The Sitapahar anticline is about 70 km (N-S) long and 12 km (E-W) wide and covers about 550 sq. km of Rangamati District. Our studied area covers about 22˚39′26.69″ N to 22˚30'2.47″N latitude and 92˚10′24.33″ E to 92˚12'57.96″E longitude respectively.



Map 1: Location map of Rangamati District

1.2 Methodology

The areas that were being investigated, was taken along the road-cut section and stream cut section, where the rocks are being well exposed. For surveying in the field, traversing method was used. By this method distance were measured by a process which is known as steeping/pacing. Then step/pace count was converted into feet. One member of each team counted him/her steps. We had G.P.S (Global positional system) by which we measured longitude, latitude. Clinometers were also used for measuring the attitude of beds. The information was plotted on the map to get a clear view of the observed area hence to convert the base map into a geological map.

Rock samples have been studied visually and observations have been written in field notebook and then plotted on the map according to their geographic locations, One of the key observations include identification of the sedimentary structures and understand the significance of that structure in the context of depositional setting.

Mapable litho-stratigraphic units have been classified based on lithology (rock assemblages). Stratigraphic correlation among different section of the area has been done. In order to understand the structural geology of the area, structural measurement (dip and strike) have been taken and immediately plotted on the map. Geological cross-section has been constructed to understand the subsurface geology.

1.3 Aims and Objectives

The general aims and objectives of the field investigation is -

1. To acquire a practical knowledge of the geology of the area.
2. To investigate the nature and types of the exposed sedimentary rocks of the studied area.
3. To know the depositional environment of these rocks.
4. To know the topographic patterns of the studied area.

5. To establish individual and distinct lithostratigraphic units as a basis of correlation.
6. To correlate the observed stratigraphic sections with standard geologic column.
7. To study the associated minor and major structures in the investigated area.
8. To make a standard geological field report and convert a Base Map into a Geological Map by collection of data and other pertinent information.

1.4 Previous Investigation

For the presence of natural exposure and possibility of hydrocarbon presence this area has been interesting to geologists since 19th century. Many investigation teams investigate this area in order to find out economically important geological elements and also to know the geology of the area. The Sitapahar anticline attracted many Geologists since the beginning of the century.

- After the Second World War, the Burma Oil Company had carried out a quick reconnaissance survey of the entire folded belt of the eastern part of Bangladesh and made a preliminary map of the Sitapahar Anticline.
- In the early sixties the OGDC made several traverses across the Sitapahar Anticline along the several streams or road tracts.
- Brunnschweiler reported on the geology of the Indo-Burman Ranges in 1966.
- N.A parker of the U.S geological survey and M.A Maroof Khan of the Geological survey of Pakistan carried out a geological investigation in 1969 along the Chandraghona- Kaptai road cut section for the collection of clay to test their suitability as a raw material for light material for weight aggregates.
- Brunnschweiler reported on Indo-Burman Ranges, Mesozoic-Cenozoic Orogenic Belts in 1974.
- Rao described the Geology and Hydrocarbon potential of a part of Assam- Arakan Basin and its adjoining region in 1983.

- In 1988 Shell Oil Company attempted to drill a deep exploration well on the Sitapahar anticline. This was abandoned at a depth of1377m. Prior to the drilling shell attempted to interpret the subsurface structural configuration with seismic survey.
- Everett, Orville and Staskowski reported on Regional tectonics of Myanmar and adjacent region in 1989.
- Alam reported on Tide dominated sedimentation in the upper Tertiary succession of Sitapahar Anticline in 1995.

1.5 Equipment used for Investigation

The following equipments were used during field work-

1. Base Map: To locate the observed information (Attitude, lithology) in the base map.
2. Clinometer: It is used for structural measurement (Strike, Dip and Dip Amount).
3. Hammer: It is used to find out proper beds or unweathered bedding planes by removing the weathering beds and is used for sampling.
4. Scraper: To expose the bed and collect sample.
5. Pocket Lens: To identify grain size and shape.
6. Hydrochloric Acid (HCl): To identify the cementing materials of the rock.
7. Sample Bag: To collect the samples.
8. Field Notebook: To note all the field information.
9. Camera: To take the photographs.

Chapter 02

Physical features of the Studied Area

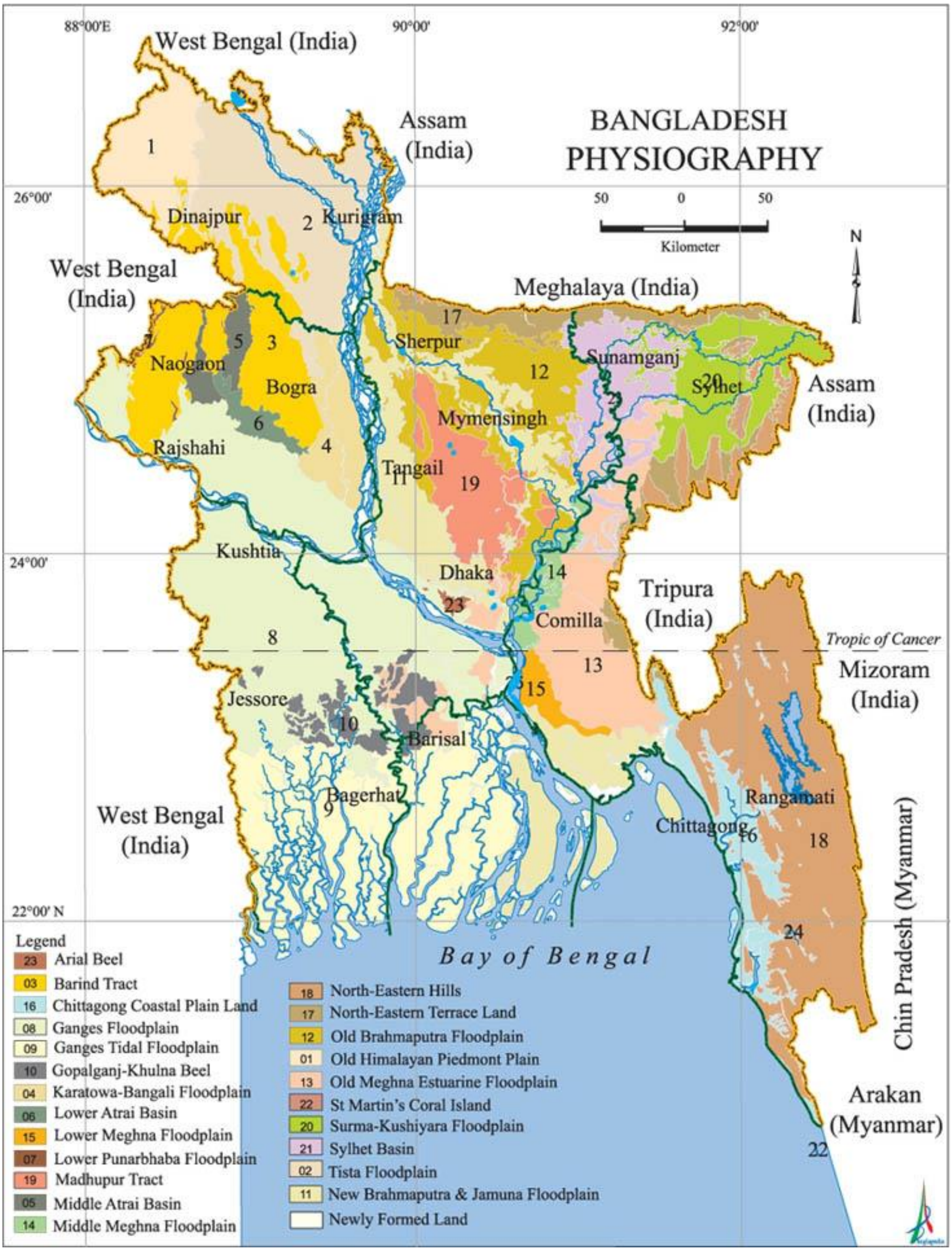
6. Physiography
7. Drainage System
8. Vegetation and Cultivation
9. Climate

2.1 Physiography

Physiography can be described as the physical and biological features of an area. Physical features mean topography, relief, drainage, climate etc. Biological features mean vegetation, cultivation, wildlife, population etc.

Reimann (1993) has subdivided Bangladesh into nine subdivisions. According to his subdivisions, the studied area is situated in Chittagong Hill Tract. Sitapahar and its adjoining area may vary physiographically on the basis of structures, topography and rock types. The investigated area is hilly region with irregular topography. These are characterized by a number of hillocks, spurs, ridges, and valleys. This region is highly designated by valley with parallel ridges where the ridges are parallel to the regional structure of Chittagong hill range trending towards the NNW-SSE direction.

The average elevation of the Sitapahar Anticline is 167 meters where it ranges from 16 meters to 335 meters. Most of the elevated area is eroded and elevation is reduced. But the resistance of the rocks makes it hard for erosion to occur unless any other natural force like earthquake acts. The slopes of Sitapahar Anticline are very rugged and difficult to climb. The structure reflects the lithologic and structural control over the topography. It is assumed that the higher the hills the more resistant the rocks are.



Map 2: Physiographic map of Bangladesh

2.2 Drainage System

The Karnaphuli River is the major river that drained the area, which is running towards an East- West direction. This is the most important and largest river of the Chittagong Hill Tracts, rising from the western slope of Lushai Hill in India. There are numerous streams and streamlets, more or less dendritic patterned. These streams, locally named as “Chara” or “Chari”, is of subsequent or consequent type. The most important tributaries are Manik Chari, Ghagra Chari, Sundari Chari, etc. During the rainy season, the Charas reemerge into life with their strong current, eroding the adjoining areas. But, they are mostly dry during winter season. A large water body, known as the Kaptai Lake was made for hydro-electric project in the eastern flank. Even though the investigated area is hilly terrain, groundwater prospect of the area is fairly good. Shallow hand tube well can reach to groundwater and thus there is no problem of drinking water.

2.3 Vegetation and Cultivation

The investigated hilly areas were abundant with biodiversity, but as of today, the impact of population growth has led to the devastation of various tree species and thus, forests. Despite all this, more or less evergreen vegetation were seen in the observed area that protect the land from erosion, because of differential rainfall and soil composition. The vegetation shows significant regional variation ranging from grass land to deduce mixed forest. Bamboo and Khagras are predominant in these forests. Besides long grasses, herbs, cucumber, segus, lozzaboti etc. are very common in the hilly region. The artificial reserve forests, with different precious trees like eucalyptus, mahogany etc., has been ground up to almost all season under the Forestry Department of Bangladesh. The slope of hills are cultivated by “Joom system” and the adjacent Plain lands are used or general cultivation. The staple agricultural products are paddy, potato, tomato, bean, jute, cotton, vegetables etc.

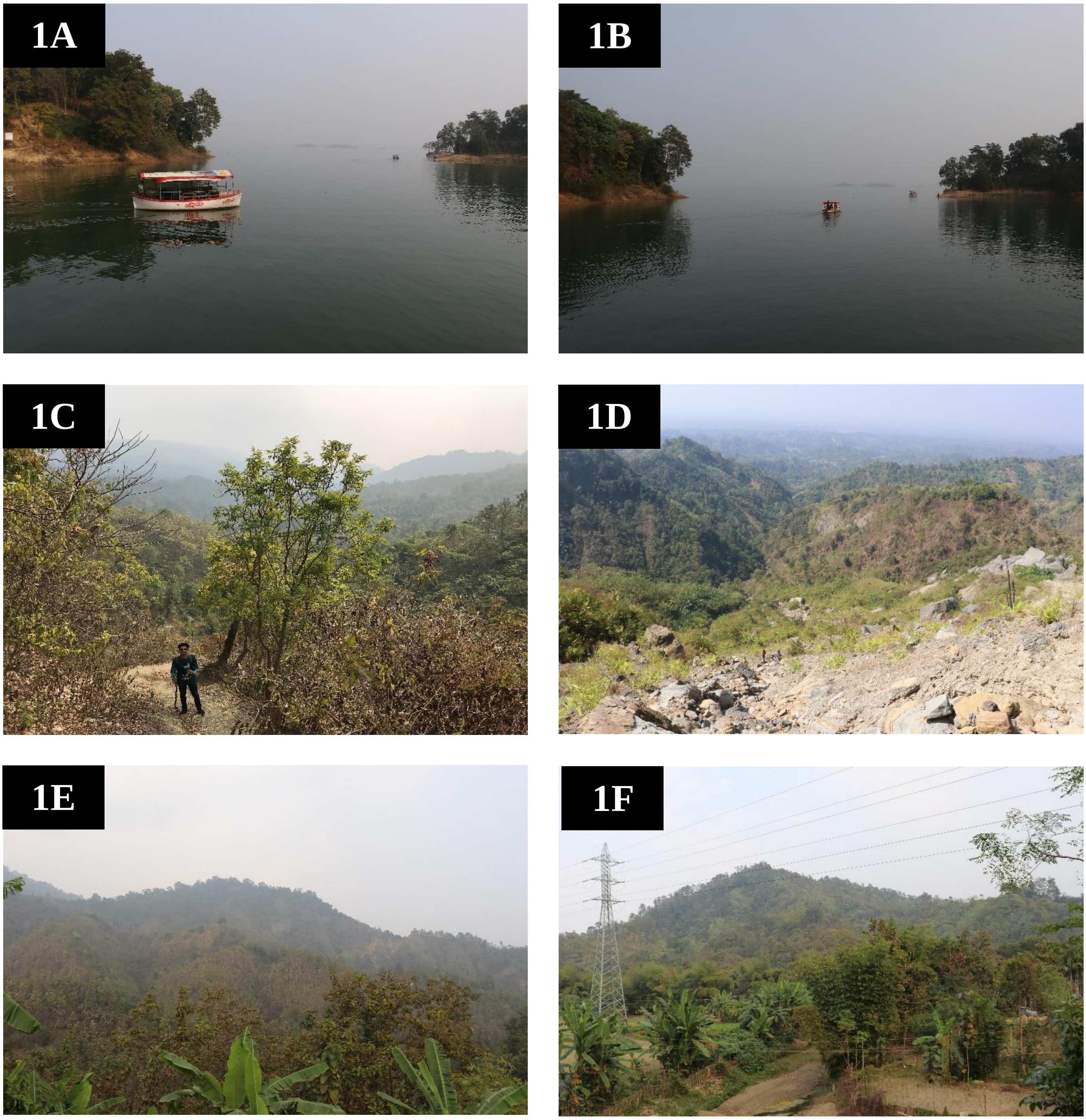


Plate 1: *Drainage of the area (1A, 1B); Topography of the area (1C, 1D); Vegetation of the area (1E, 1F)*

2.4 Climate

The area can be characterized by tropical to sub-tropical climatic condition. The temperature of the area ranges from 90F to 65F. Three distinct seasons are seen in Rangamati and adjoining areas.

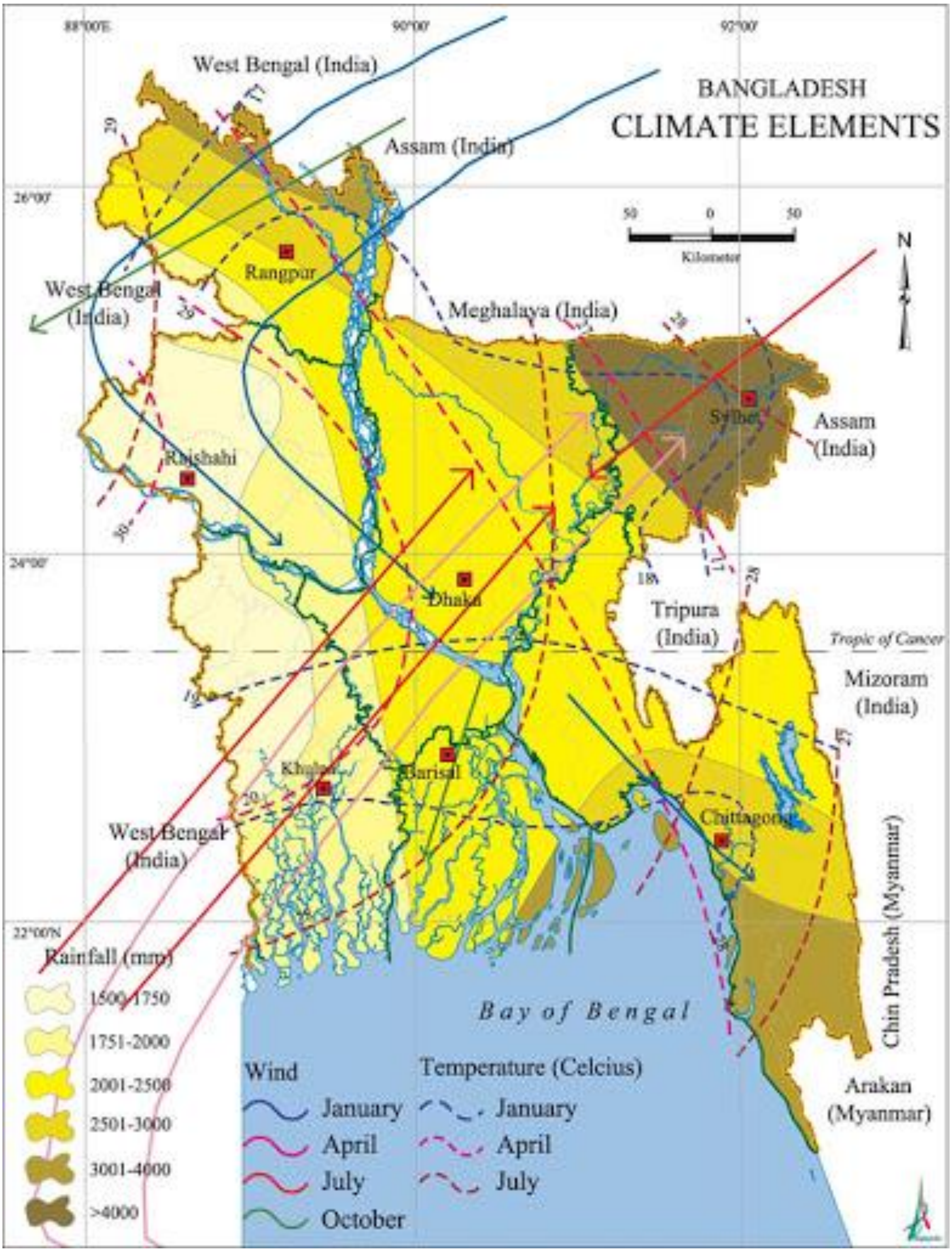
i. The summer starts from March and with high temperature and moderate precipitation, it lasts till May.
ii. In June the monsoon begins and continue up to October, with dark cloud in sky and heavy rainfall with dusty wind and often cyclonic storm.
iii. Characterized by pleasant cool and dry weather begins from November and ends in February.

The Climatic condition of the study area is full under tropical monsoon but the temperature fluctuates to the presence of Bay of Bangla and hill ranges. The Region can be divided into two main seasons:

Dry season (from November to March) and Rainy season (from June to October).

On the basis of temperature, the climate can be divided into two distinct seasons:

Cold season (from November to January) and Warm season (from March to October).



Map 3: Climatic Map of Bangladesh

Chapter 03

Geological Setting of the Area

10. Tectonic Elements of Bengal Basin

11. Structural Setting

12. Geological Evolution

13. Stratigraphy of the Area

Chapter- 4

Sedimentary Petrology

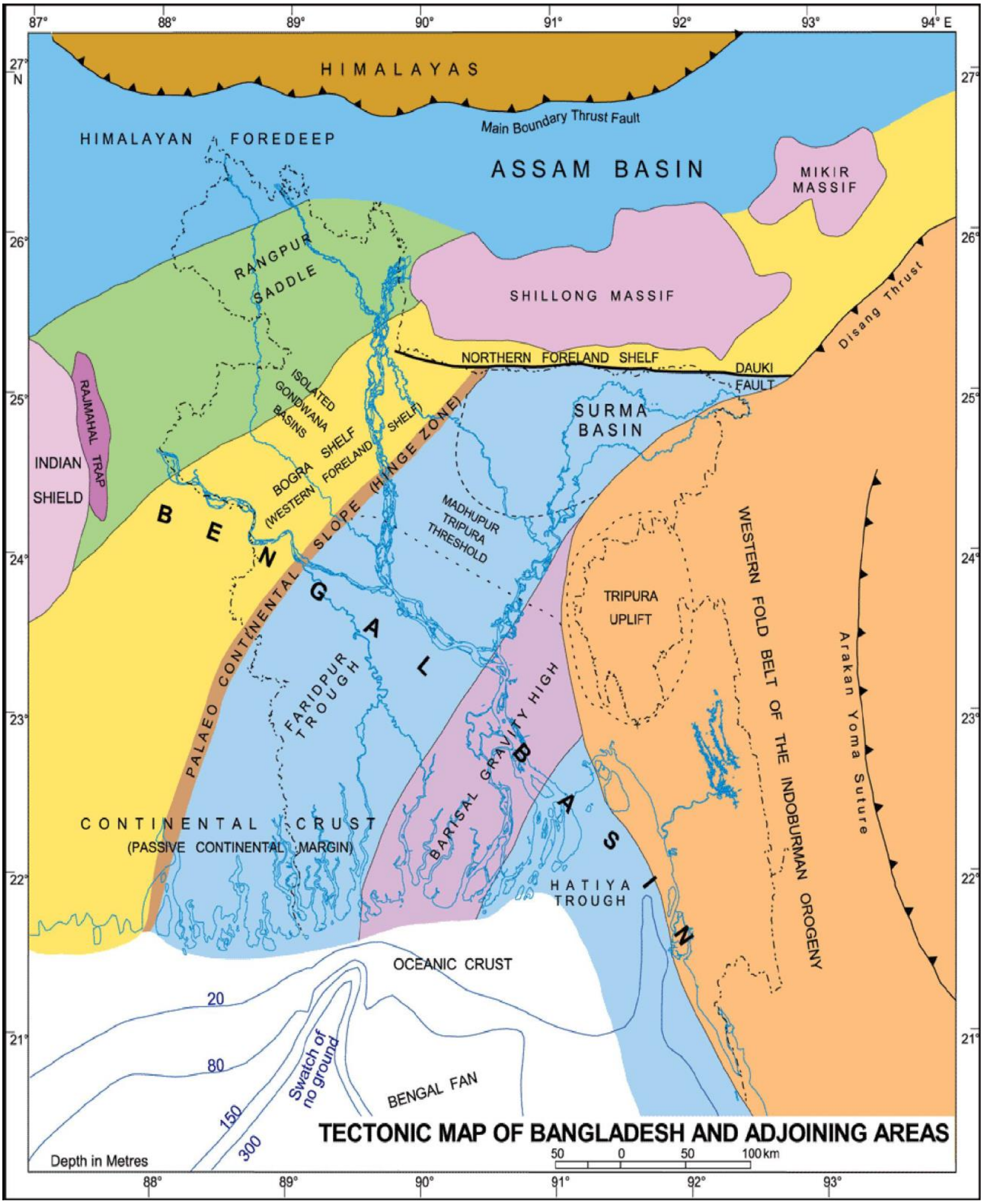
3.1 Tectonic Elements of Bengal Basin

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



Map 4: Tectonic Map of Bangladesh and adjoining areas (Guha, 1978 and Reimann, 1993)

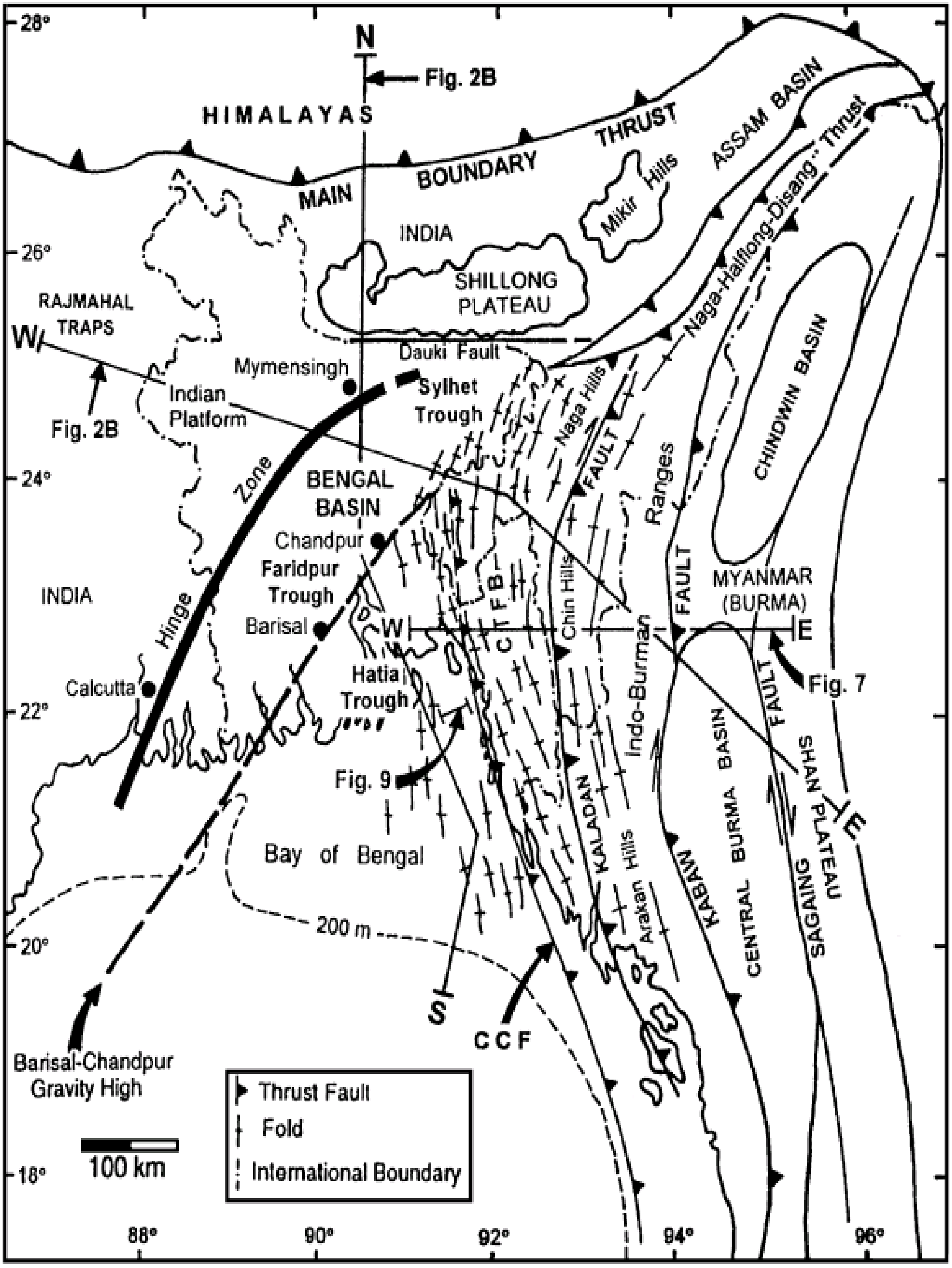
3.2 Structural Setting

The Chittagong Hill Tracts is originated as a result of the collision between India and Asia. Chittagong Hill Tracts the Upper Tertiary sandy-argillaceous sediments have been folded into a series of long sub-meridional (NNW-SSE) anticlines and synclines represented in the surface topography by elongated hill ranges and intervening valleys. The folded structures are characterized by en-echelon orientation with an increasing degree of intensity and complexity toward the east. Accordingly, the folded flank is divided into three parallel almost N-S trending zones from west to east as:

(a) The Western Zone is characterized by simple box-like or similar shaped anticlines with steep flanks and gentle crests separated by gentle synclines, viz Matamuhuri anticline, Semutang anticline, etc.

(b) The Middle Zone is characterized by more compressed structures, other than just simple boxlike folds, with ridge like asymmetric anticlines frequently associated with faults and separated by narrow synclines viz Sitapahar anticline, Bandarban anticline, Gilasari anticline, Patiya anticline, Changohtung anticline, Tulamura anticline, Kaptai syncline, Alikadam syncline, etc.

(c) The Eastern Zone is characterized by highly disturbed narrow anticlines with steep clipping flanks and mostly associated with thrust faults, viz Belasari anticline, Subalong syncline, Utanchatra anticline, Barkal anticline, Mowdac anticline, Ratlong anticline, Kasalong syncline (Khan, 1991).



Map 5: Regional map showing the tectonic elements of the Bengal Basin and surrounding arears

(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).

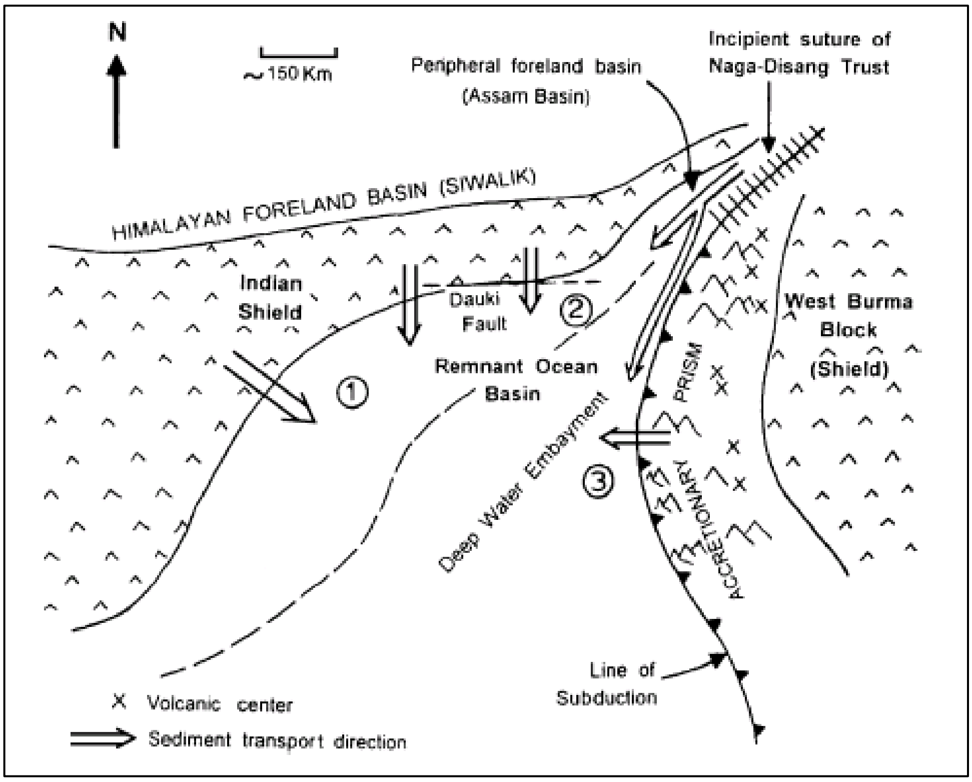


Figure 1: Schematic Early Miocene paleogeographic representation of the Bengal Basin and surrounding regions in terms of the Plate tectonic model.

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 Area

The stratigraphy of the CTFB is given below (Alam and Gani, 1999):

Traditional stratigraphic classification for the CTFB

Regional (CTFB) nomenclature[a]				Mirinja Anticline[b]			Sitapahar Anticline[b]	
Age (approx.)	Group	Formation	Thickness (approx.) (m)	Age (approx.)	Composite sequence	Thickness (m)	Composite sequence	Thickness (m)
Recent		Alluvium		Recent				
Plio-Pleistocene		Dupitila	500					
Pliocene	Tipam Group	Girujan Clay	200	Plio-Pleistocene	A	1073+	A	1080+
		Tipam Sandstone	900					
Miocene	Surma Group	Bokabil	1500	Late Miocene	B	1293	B	953+
				Middle Miocene	C	590+	C	1128+
		Bhuban	3000+					
	Lower contact not confirmed							

Figure 2: Traditional Stratigraphic succession for the CTFB

Chapter 04

Sedimentary Petrology

14. Major Rock Types
15. Sedimentary Structures
16. Sedimentary Facies Analysis
17. Grain Size Analysis
18. Description of Deposition Environment

Chapter- 4
Sedimentary Petrology

Petrology is the study of rocks, their occurrences, composition, origin and evolution. Petrology focuses primarily on the rock formation, or petro-genesis. A petrological description includes definition of the unit in which the rock occurs, its attitude and structure, its mineralogy and chemical composition, and conclusions regarding its origin. Based on our investigation it can be concluded that the rocks observed in the area are of sedimentary origin and occurred as lithostratigraphic sequences.

The extensive analysis of the sedimentary petrology of the area is divided into four parts:

4.1 Major Rock Types

4.1.1 Yellowish Brown Sandstone

The observed rock type is yellowish brown colored associated with medium to coarse grained sand size particles which is massive in structure. In addition, sedimentary structures like cross lamination and trough cross bedding are also present in this rock type. However, the rock is highly permeable and loosely compacted and friable. The cementing materials might be ferruginous. The yellowish brown sandstone contains clay galls and iron incrustation.

4.1.2 Crudely Bedded Yellowish Brown Sandstone

Mainly yellowish brown in color, occasionally shows gray color. It is fundamentally composed of medium to coarse grained sand sized particles. It is mostly crudely bedded, sometimes containing trough cross bedding structure. The rock specimen is moderately permeable and compacted. The cementing material might be ferruginous also. Moreover, thin discontinuous layer of clay and clay galls are also present in this rock type.

4.1.3 Calcareous Sandstone

Gray in color, medium to fine grain size, hard and compact, both thick and thin bedded and calcareous cementing material present. Occurs mainly as band.

4.1.4 Sandy Shale

Sandy shale is dominantly grayish in color and mainly composed of fine to medium grained sand and silt sized particles. Sedimentary structures like micro-cross lamination, lenticular bedding and wavy bedding are often found in this rock type associated with some soft deformational structures like load structure. The rock is moderately permeable and compacted. The cementing material might be argillaceous.

4.1.5 Silty Shale

Silty shale is dominantly grayish in color, often showing some bluish color also. It is mainly composed of fine grained clay and silt sized particles. Despite some appearance of thin lamination, it is mostly laminated. It shows relatively low permeability and high compaction. Calcareous bands are also found in this rock type. Cementing materials might be argillaceous.

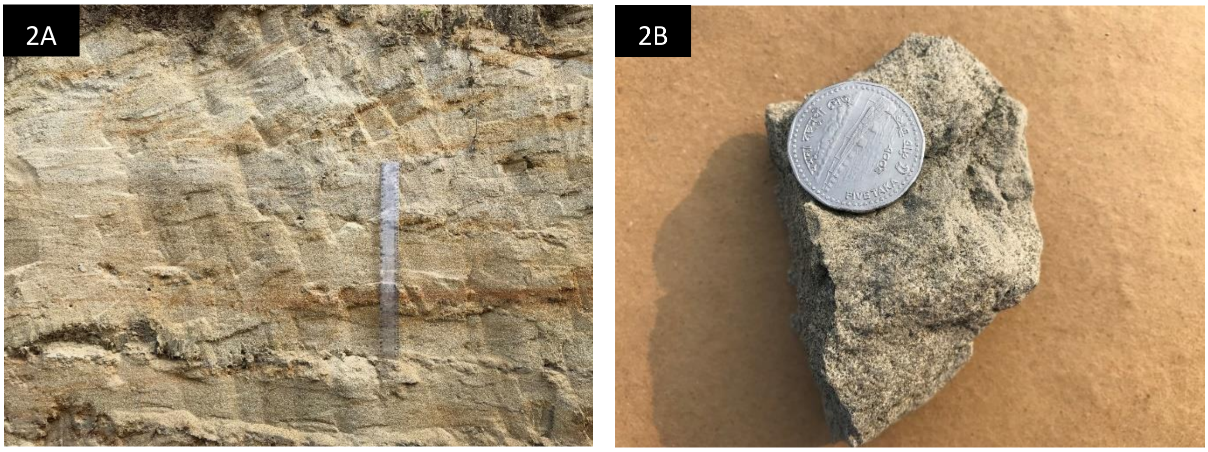


Plate 2: *Loose yellowish brown sandstone (2A), Crudely Bedded YB Sandstone (2B)*

4.2 Sedimentary Structures

Sedimentary Structures are large scale features produced within a depositional environment during or no longer after deposition.

Sedimentary structures include all kinds of features formed at the time of deposition. Sediments and sedimentary rocks are characterized by bedding, which occurs when layers of sediment, with different particle sizes are deposited on top of each other. These beds range from millimeters to centimeters thick and can even go to meters or multiple meters thick. Structures that are produced at the same time as the sedimentary rock in which they occur are called primary sedimentary structures. Examples include bedding or stratification, graded bedding, and cross-bedding. Whereas other sedimentary structures like concretions form well after deposition and penecontemporaneous modification are known as secondary structures. Finally, there is another type of structure, called organic sedimentary structures which includes structures like organic burrows and tracks.

Based on our field observation we found primary sedimentary structures such as Lenticular Bedding, Nodular Structure, Cross Bedding, Wavy Bedding, Trough Cross Bedding etc. We also observed secondary structures like iron concretions. Finally we found some organic sedimentary structures such as burrows and plant impressions.

4.2.1 Nodular Structure

Nodular is used to describe sediment or sedimentary rock composed of scattered to loosely packed nodules in matrix of like or unlike character. It is also used to describe mineral aggregates that occur in the form of nodules.

We found this structure only in Bluish gray shale and it was the fundamental structure of that rock type.

4.2.2 Wavy Bedding

Wavy bedding is a form of heterolithic sediment characterized by interbedded rippled sands and mud layers. Based on our observation, wavy bedding was found in both bluish gray shale and sandy shale.

4.2.3 Lenticular Bedding

Lenticular Bedding is a structure formed by interbedded mud and ripple cross laminated sand in which the ripples or sand lenses are discontinuous and isolated in both a vertical and a horizontal direction. We also observed this structure in Sandy Shale and Bluish Gray Shale.

4.2.4 Flaser Bedding

Flaser beds are a sedimentary, bi-directional, bedding pattern created when a sediment is exposed to intermittent flows, leading to alternating sand and mud layers. While flaser beds typically form in tidal environments, they can (rarely) form in fluvial conditions - on point bars or in ephemeral streams.

We observed this structure in Sandy Shale.

4.2.5 Trough Cross Bedding

Trough cross bedding consists of cross bedded units in which one or both bounding surfaces are curved. The units are trough shaped sets consisting of an elongate scour filled with curved fore set laminae that commonly have a tangential relationship to the base of the set. This structure was observed in Yellowish Brown Sandstone.

4.2.6 Tabular Cross Bedding

Tabular (planar) cross-beds consist of cross-bedded units that are large in horizontal extent relative to set thickness and that have essentially planar bounding surfaces. Tabular cross-bedding is formed mainly by migration of large-scale, straight-crested ripples and dunes. It forms during lower-flow regimes.

4.2.7 Massive Structure

Rocks are called massive when beds are homogeneous and lacking in internal structure.

We observed this structure in Yellowish Brown Sandstone.

Secondary Sedimentary Structures observed are given below:

4.2.8 Iron Incrustation

A crust or hard coating of anything upon or within a body, as a deposit of lime, sediment, etc., from water on the inner surface of a steam boiler.

We observed this structure in almost every section.

4.2.9 Clay Gall

When a patch of clay or mud dries out, the upper surface cracks and peels away from the upper layers. These thin leaves of clay may occasionally be transported a short distance and deposited in sand or in some kind of sediment in the form of flat or lensed shape clay galls, generally oriented parallel to the bedding.

We observed this structure in Yellowish Brown Sandstone and others.

Organic Sedimentary Structures that we observed in our field work are as follows:

4.2.10 Burrows

A **burrow** is a hole or tunnel excavated into the ground by an animal to create a space suitable for habitation, temporary refuge, or as a byproduct of locomotion.

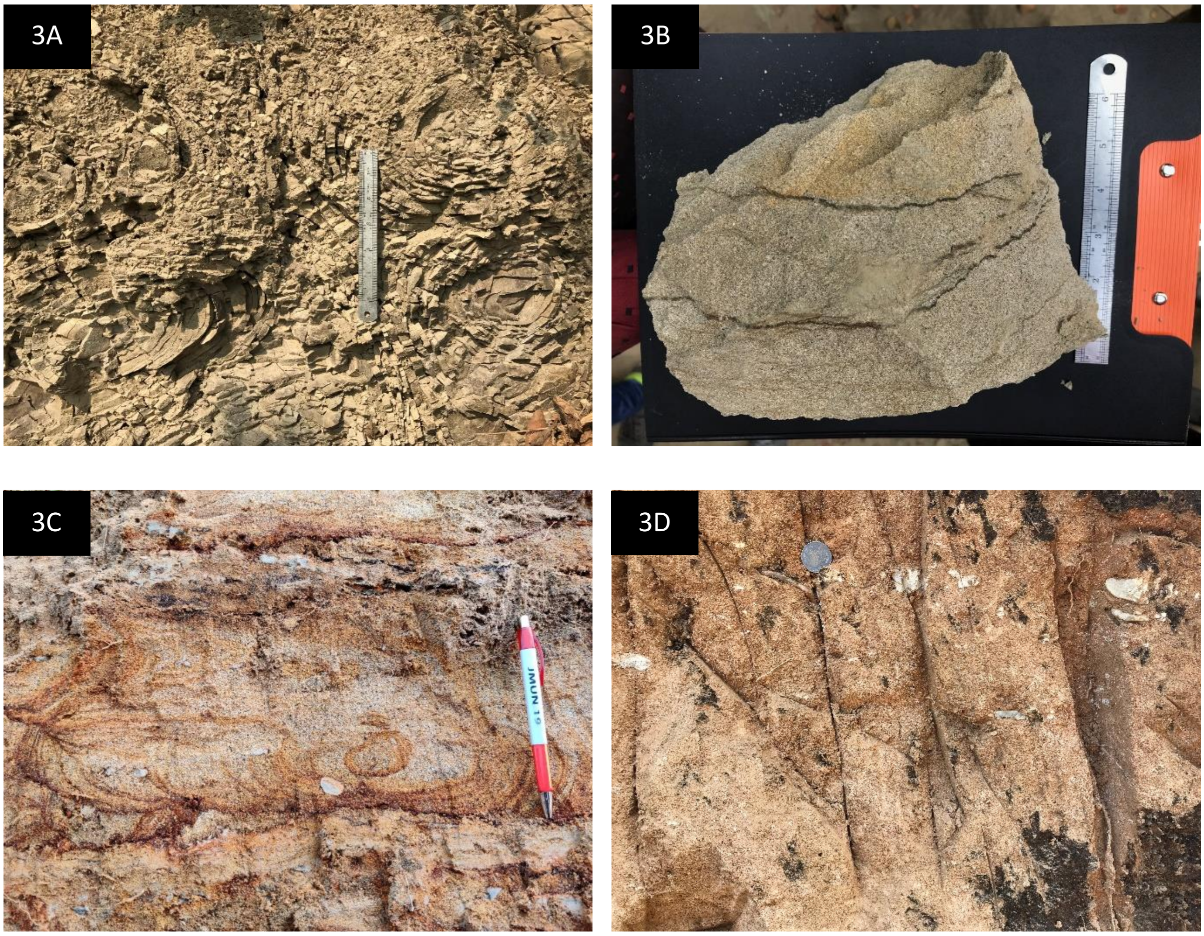


Plate 3: *Nodular Structure (3A), Flaser Bedding (3B), Iron Incrustation (3C), Clay Gall (3D)*

4.3 Sedimentary Facies Analysis

Facies can be defined as the overall characteristics of a rock unit that reflect its origin and differentiate the unit from others around it. Facies is classified based on three characteristics and these are:

1. Lithofacies: Based on lithology and physical characteristics of rocks.
2. Biofacies : Based on flora and fauna assemblage.
3. Ichnofacies: Focuses on the trace fossils of rocks *(G.Nichols.1999)*.

4.3.1 Lithofacies: Based on the analysis of color, texture, composition, and sedimentary structure of the rocks, two major lithofacies were identified on the Rangamati Hill range area and these are as follows:

1. Sandstone Facies
2. Shale Facies

Sandstone Facies:

1. **Massive Sandstone:** Yellowish brown in color, medium to fine grained, loosely compacted, moderately sorted, highly porous, found Iron layer due to oxidation and leaching, Clay gall and clay layer were found. Small scale trough cross bedding, cross lamination and tabular cross bedding were also found.
2. **Ripple Cross Laminated Sandstone:** Gray color, very fine grained, ripples are assymentric in profiles and sinuous crested. This facies is predominant in the investigated area. This type of facies deposited in abandoned part of channel.
3. **Moderately Compacted Sandstone:** Yellowish brown in color, fine to very fine grain size, massive structure, highly permeable. It contains iron concretion, clay gall and burrows.
4. **Trough Cross Bedded Sandstone:** Gray in color.

4.4 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 litho logical 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:

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

Table 1: M Values

Values from	To	Equal
$-\infty$	-1ϕ	gravel
-1	0ϕ	very coarse sand
+0	$+1\phi$	coarse sand
+1	$+2\phi$	medium sand
+2	$+3\phi$	fine sand
+3	$+4\phi$	very fine sand
+4	$+8\phi$	silt
+8	$\infty\ \phi$	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:

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

Table 2: 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:

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

Table 3: 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:

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

Table 4: 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

Data Table & Calculation

Sample No : st-21

Date :

Section :

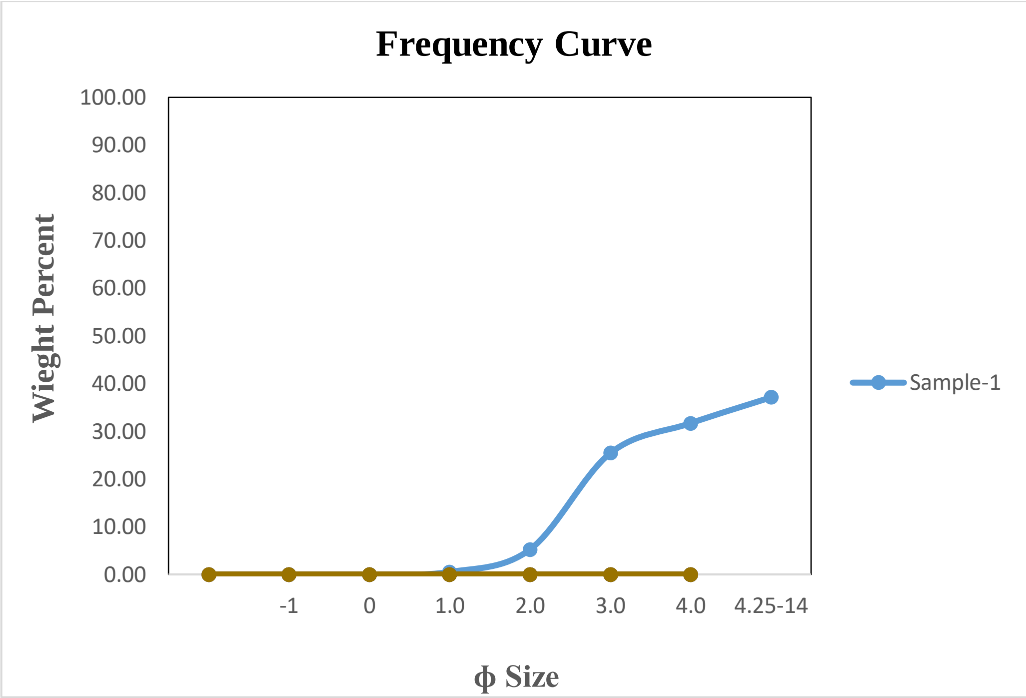
Location :

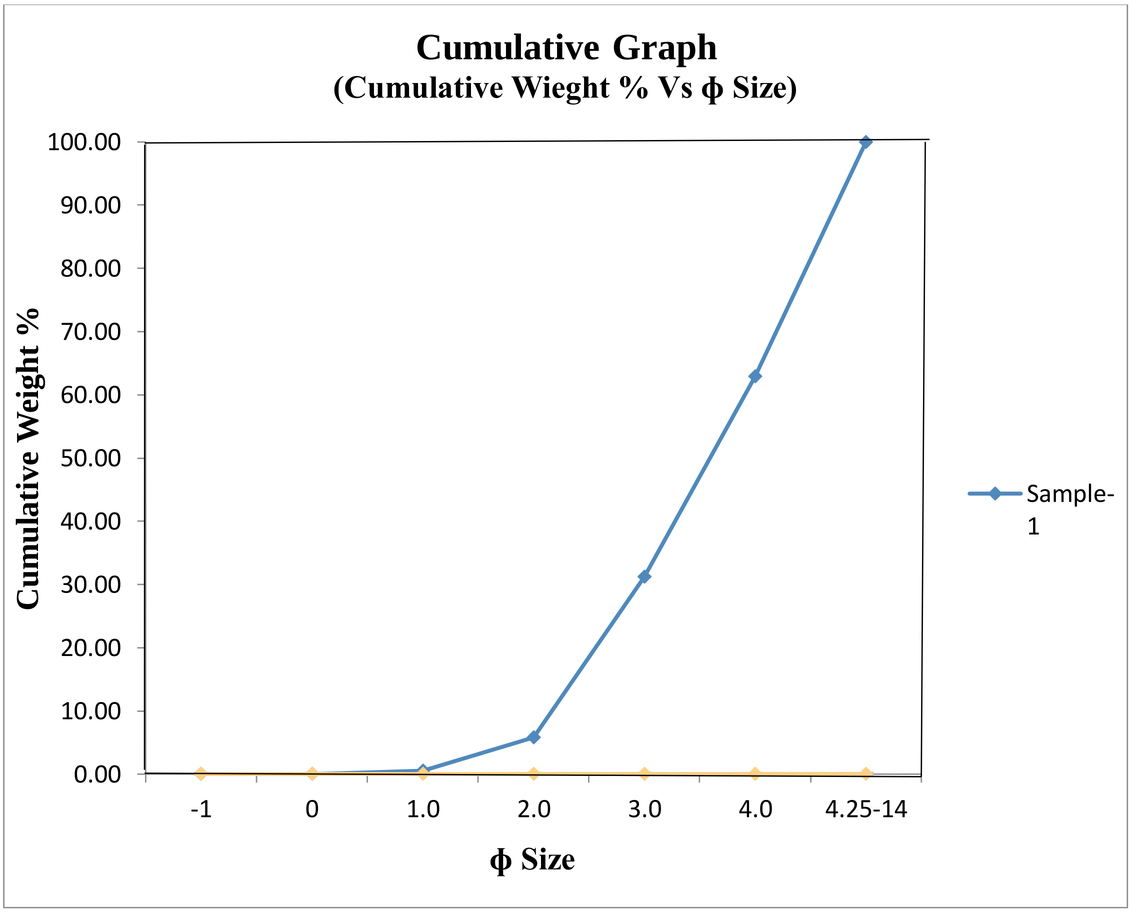
Rock type/ Facies :

Rock Unit :

Table 05: Different Grain Size Analysis-1

Mash Size (d) (mm)	ϕ Size (log 2d)	Raw Data weight (gm)	Weight Percentage	Cumulative Weight Percentage
2	-1	0.00	0.00	**0.00**
1	0	0.00	0.00	**0.00**
0.5	1.0	0.52	0.53	**0.53**
0.25	2.0	5.18	5.23	**5.76**
0.125	3.0	25.18	25.42	**31.18**
0.063	4.0	31.40	31.70	**62.88**
Pan	4.25-14	36.76	37.12	**100.00**
	Total=	**99.04**	**100.00**	


Frequency Curve
Wieght Percent
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
-1
0
1.0
2.0
3.0
4.0
4.25-14
Sample-1
ϕ Size


Cumulative Graph
(Cumulative Wieght % Vs ϕ Size)
Cumulative Weight %
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
-1
0
1.0
2.0
3.0
4.0
4.25-14
Sample-1
ϕ Size

Input Φ (Phi) value from the graph paper

Scale	Value	Scale	Value
ϕ_{05}=	**1.95**	**ϕ_{75}=**	**4.40**
ϕ_{16}=	**2.55**	**ϕ_{84}=**	**4.75**
ϕ_{25}=	**2.85**	**ϕ_{95}=**	**5.60**
ϕ_{50}=	**3.55**		

Result:

Type			Result	Comments
Graphic Mean	10.85	3.00	**3.62**	Very fine sand
Graphic Standard Deviation	0.55	0.55	**1.10**	Poorly sorted
Graphic Skewness	0.05	0.06	**0.11**	Fine Skewed
Kurtosis	3.65	3.78	**0.97**	Mesokurtic

Sample No: 19

Date :

Section :

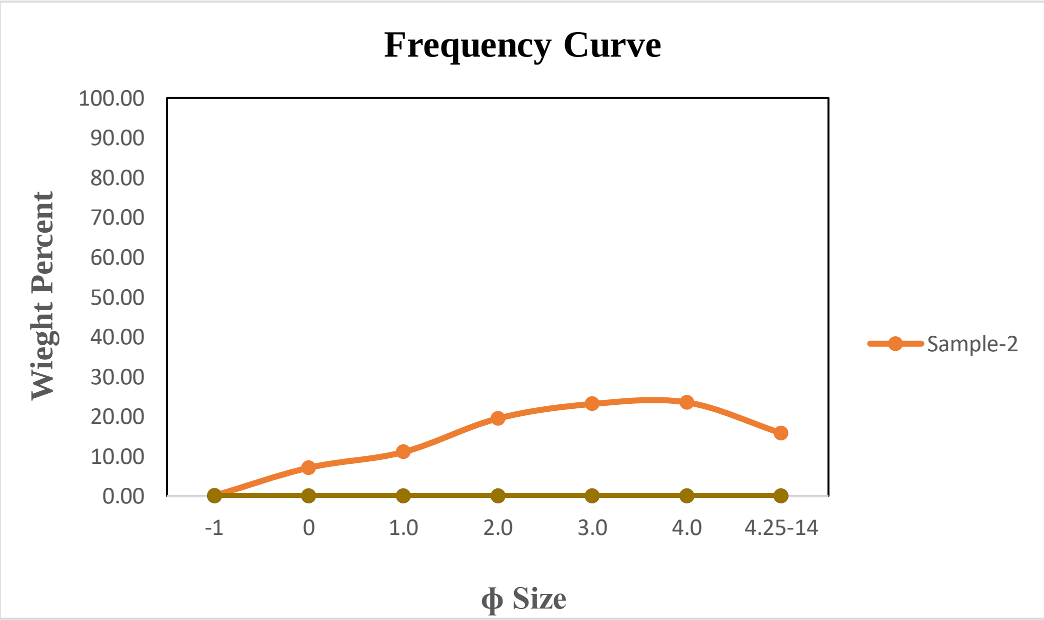
Location :

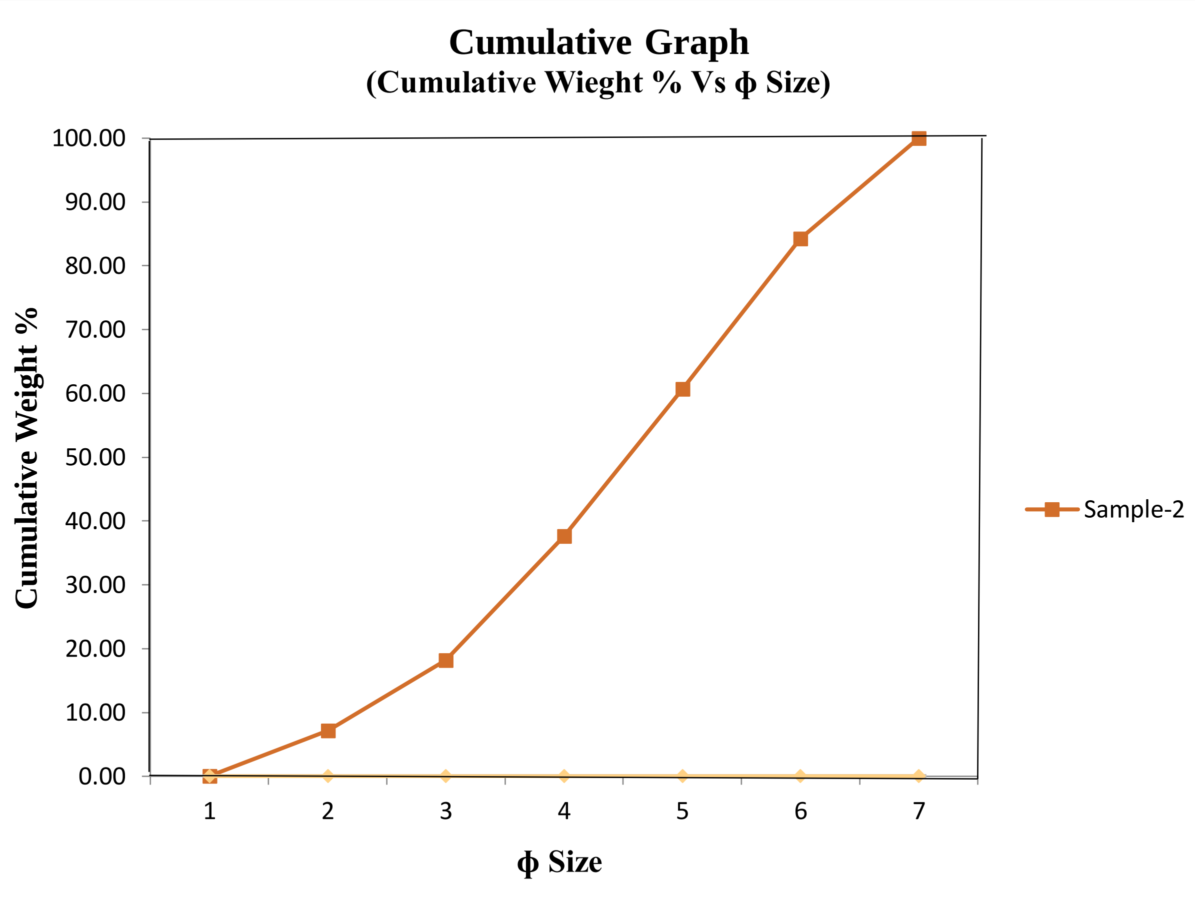
Rock type/ Facies :

Rock Unit :

Table 06: Different Grain Size Analysis- 2

Mash Size (d) (mm)	**ϕ Size (log 2d)**	**Raw Data weight (gm)**	**Weight Percentage**	**Cumulative Weight Percentage**
2	-1	0.04	0.04	**0.04**
1	0	7.09	7.09	**7.13**
0.5	1.0	11.01	11.01	**18.14**
0.25	2.0	19.45	19.45	**37.59**
0.125	3.0	23.11	23.11	**60.70**
0.063	4.0	23.52	23.52	**84.22**
Pan	4.25-14	15.78	15.78	**100.00**
	Total=	**100.00**	**100.00**	





Input ϕ (Phi) value from the graph paper

Scale	Value	Scale	Value
ϕ_{05}=	**-0.05**	ϕ_{75}=	**3.40**
ϕ_{16}=	**0.90**	ϕ_{84}=	**4.00**
ϕ_{25}=	**1.35**	ϕ_{95}=	**5.25**
ϕ_{50}=	**2.40**		

Result

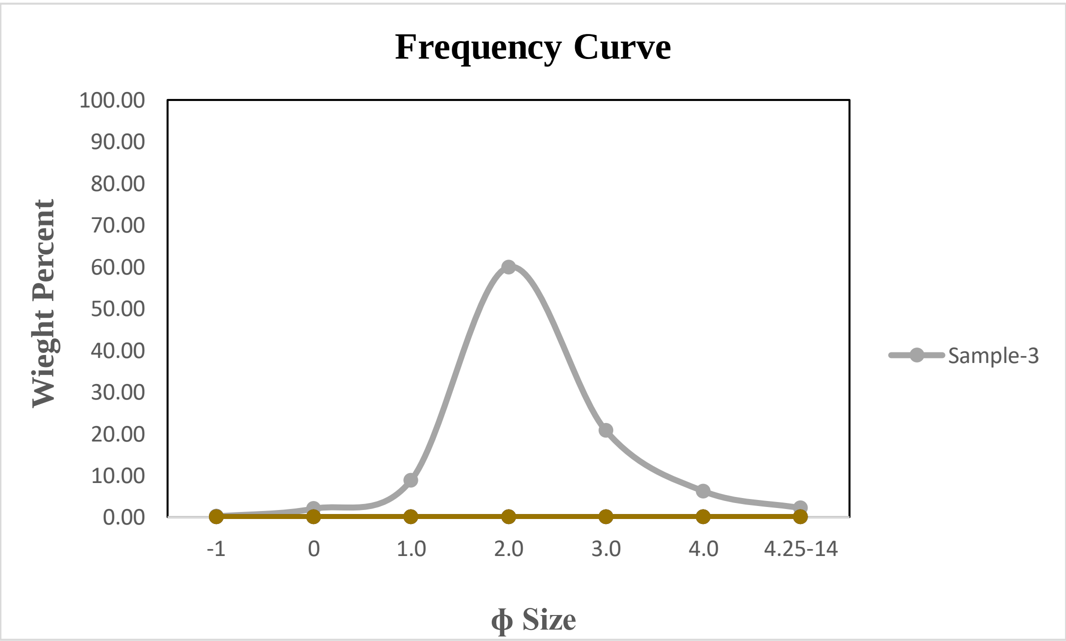
Type			Result	Comments
Graphic Mean	7.30	3.00	**2.43**	Fine sand
Graphic Standard Deviation	0.78	0.80	**1.58**	Poorly Sorted

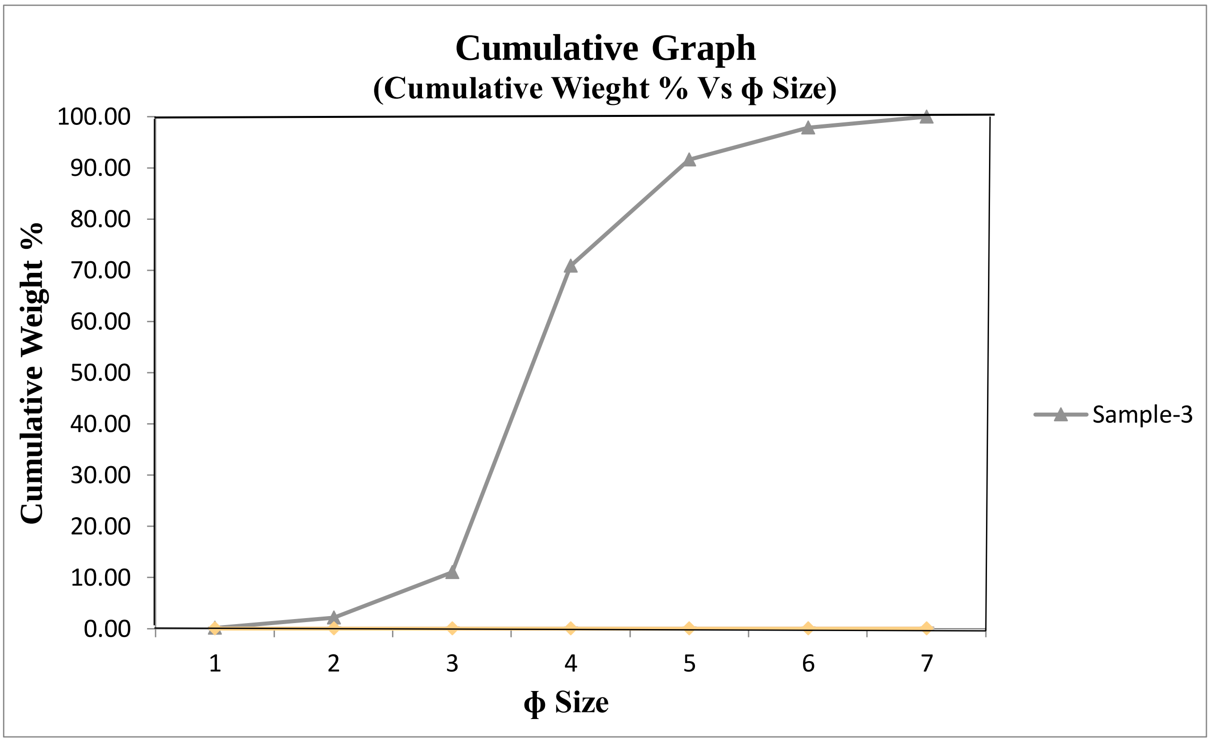
Graphic Skewness	0.02	0.04	**0.05**	Near symmetrical
Kurtosis	5.30	5.00	**1.06**	Mesokurtic

Sample No : st01
Date :
Section :
Location :
Rock type/ Facies :
Rock Unit :

Table 06: Different Grain Size Analysis- 3

Mash Size (d) (mm)	ϕ Size (log 2d)	Raw Data weight (gm)	Weight Percentage	Cumulative Weight Percentage
2	-1	0.16	0.16	**0.16**
1	0	2	2.00	**2.16**
0.5	1.0	8.84	8.84	**11.00**
0.25	2.0	59.92	59.92	**70.92**
0.125	3.0	20.7	20.70	**91.62**
0.063	4.0	6.22	6.22	**97.84**
Pan	4.25-14	2.16	2.16	**100.00**
	Total=	**100.00**	**100.00**	





Input ϕ (Phi) value from the graph paper

Scale	Value	Scale	Value
ϕ_{05}=	**0.50**	ϕ_{75}=	**2.10**
ϕ_{16}=	**1.10**	ϕ_{84}=	**2.45**
ϕ_{25}=	**1.25**	ϕ_{95}=	**3.40**
ϕ_{50}=	**1.60**		

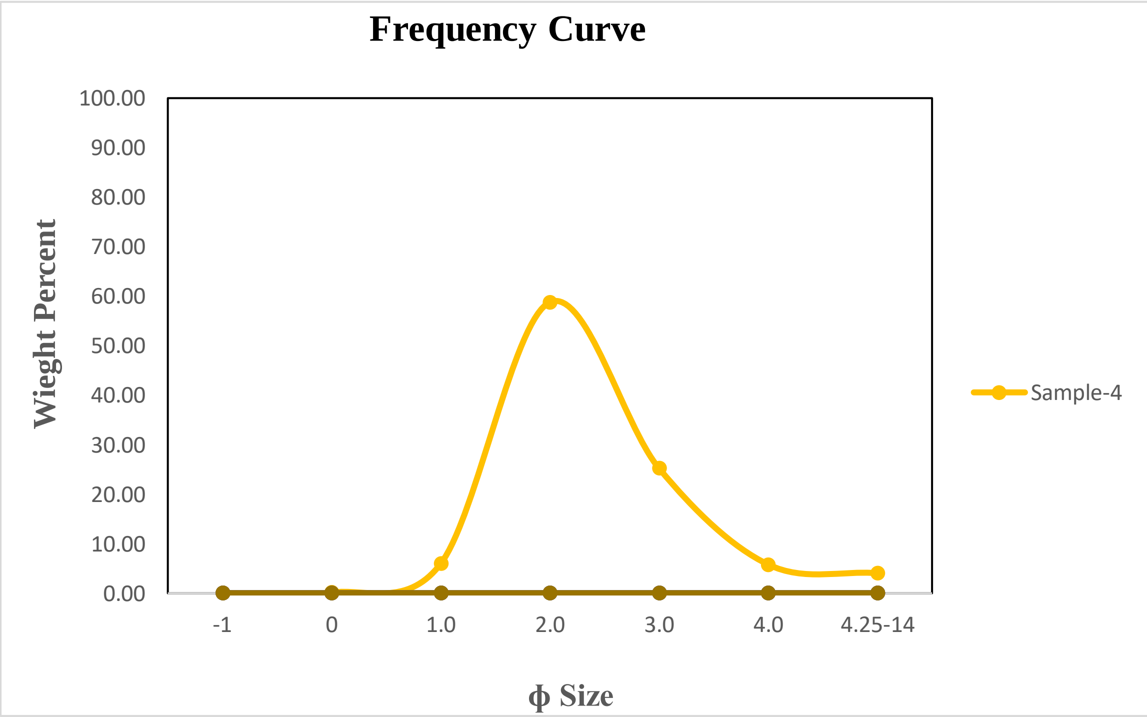
Result

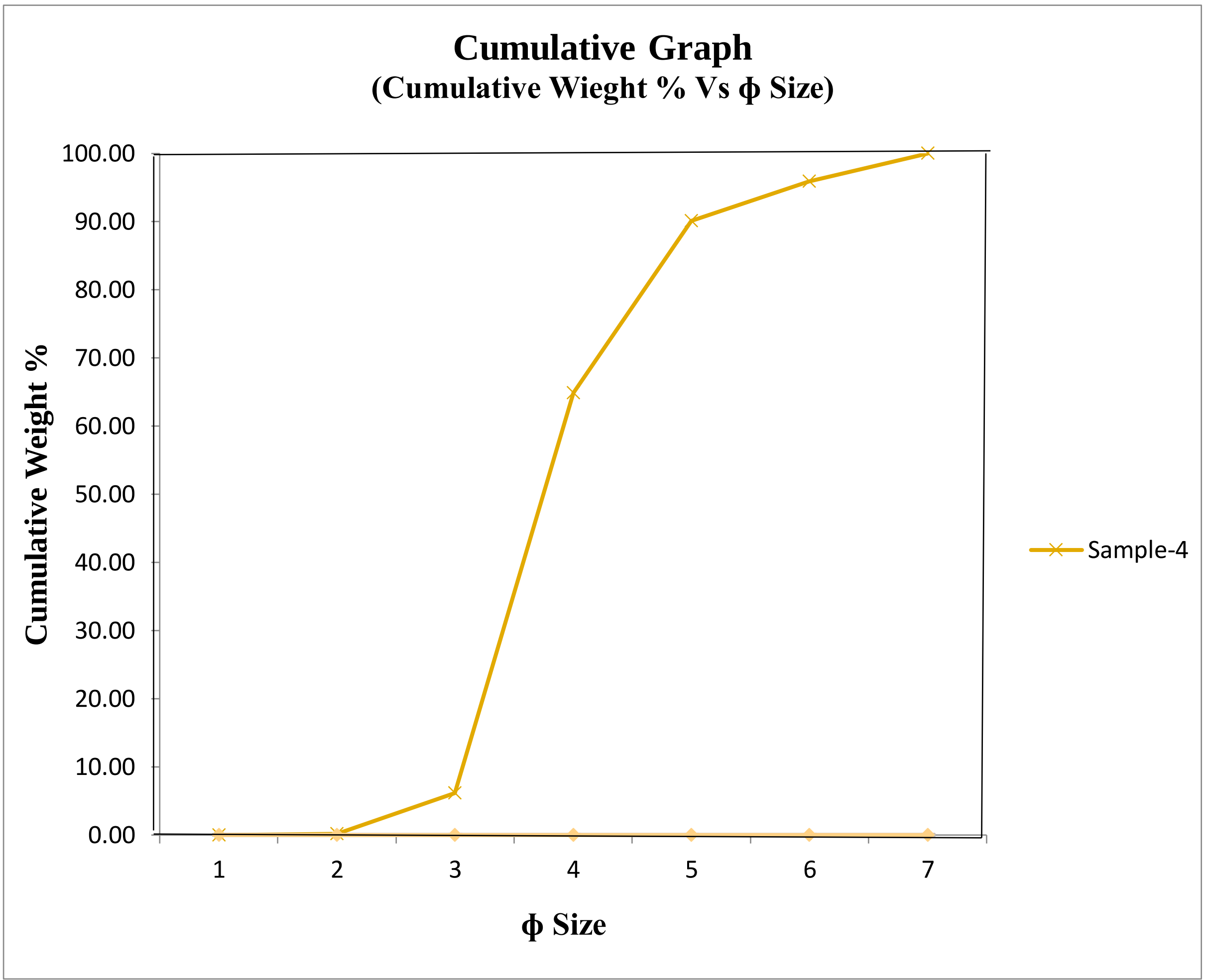
Type			Result	Comments
Graphic Mean	5.15	3.00	**1.72**	Medium Sand
Graphic Standard Deviation	0.34	0.44	**0.78**	Moderately Sorted
Graphic Skewness	0.13	0.12	**0.25**	Fine Skewed
Kurtosis	2.90	2.07	**1.40**	Leptokurtic

Sample No : 07
Date :
Section :
Location :
Rock type/ Facies :
Rock Unit :

Table 07: Different Grain Size Analysis- 4

Mash Size (d) (mm)	ϕ Size (log 2d)	Raw Data weight (gm)	Weight Percentage	Cumulative Weight Percentage
2	-1	0.00	0.00	**0.00**
1	0	0.15	0.15	**0.15**
0.5	1.0	5.97	5.99	**6.14**
0.25	2.0	58.62	58.78	**64.92**
0.125	3.0	25.14	25.21	**90.13**
0.063	4.0	5.79	5.81	**95.94**
Pan	4.25-14	4.05	4.06	**100.00**
	Total=	**99.72**	**100.00**	





Input ϕ (Phi) value from the graph paper

Scale	Value	Scale	Value
ϕ_{05}=	**0.95**	ϕ_{75}=	**2.25**
ϕ_{16}=	**1.25**	ϕ_{84}=	**2.55**
ϕ_{25}=	**1.4**	ϕ_{95}=	**3.75**
ϕ_{50}=	**1.75**		

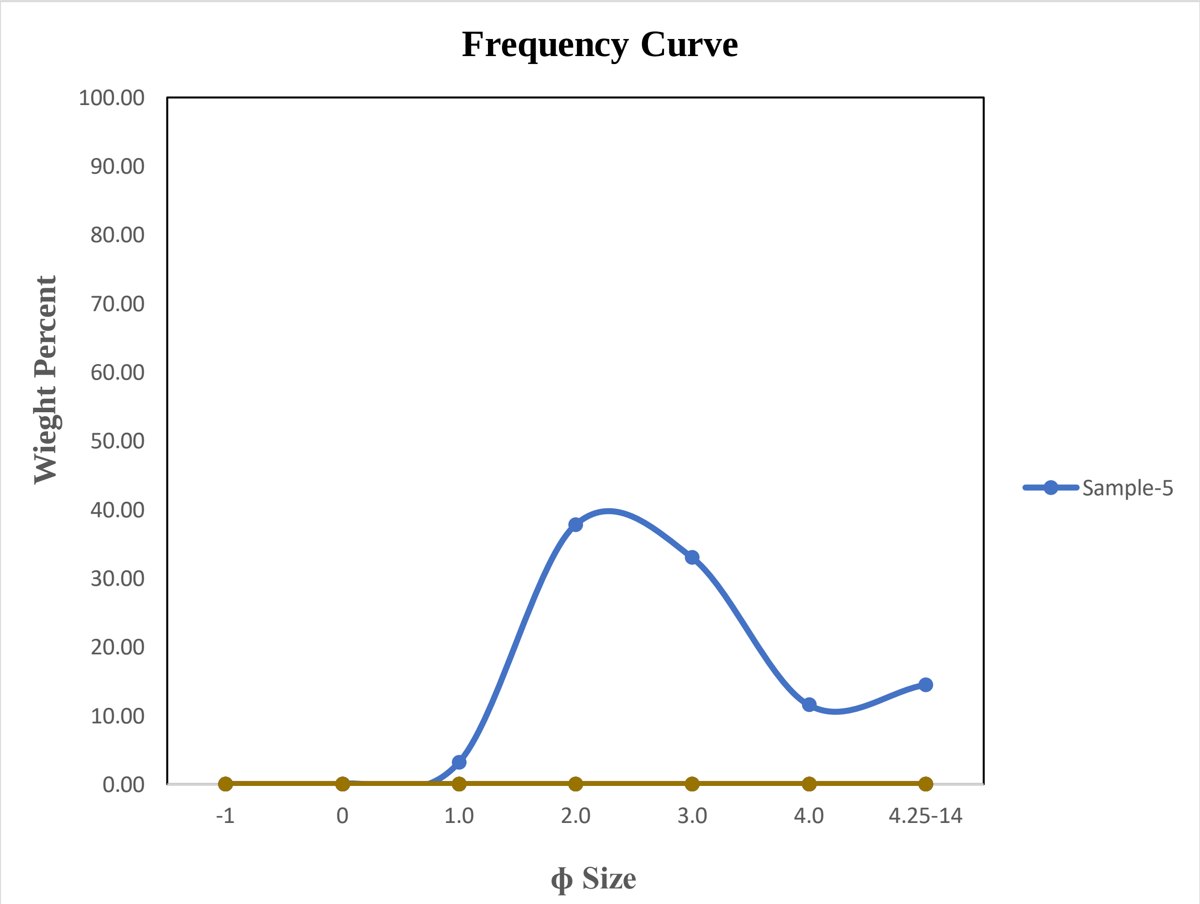
Result

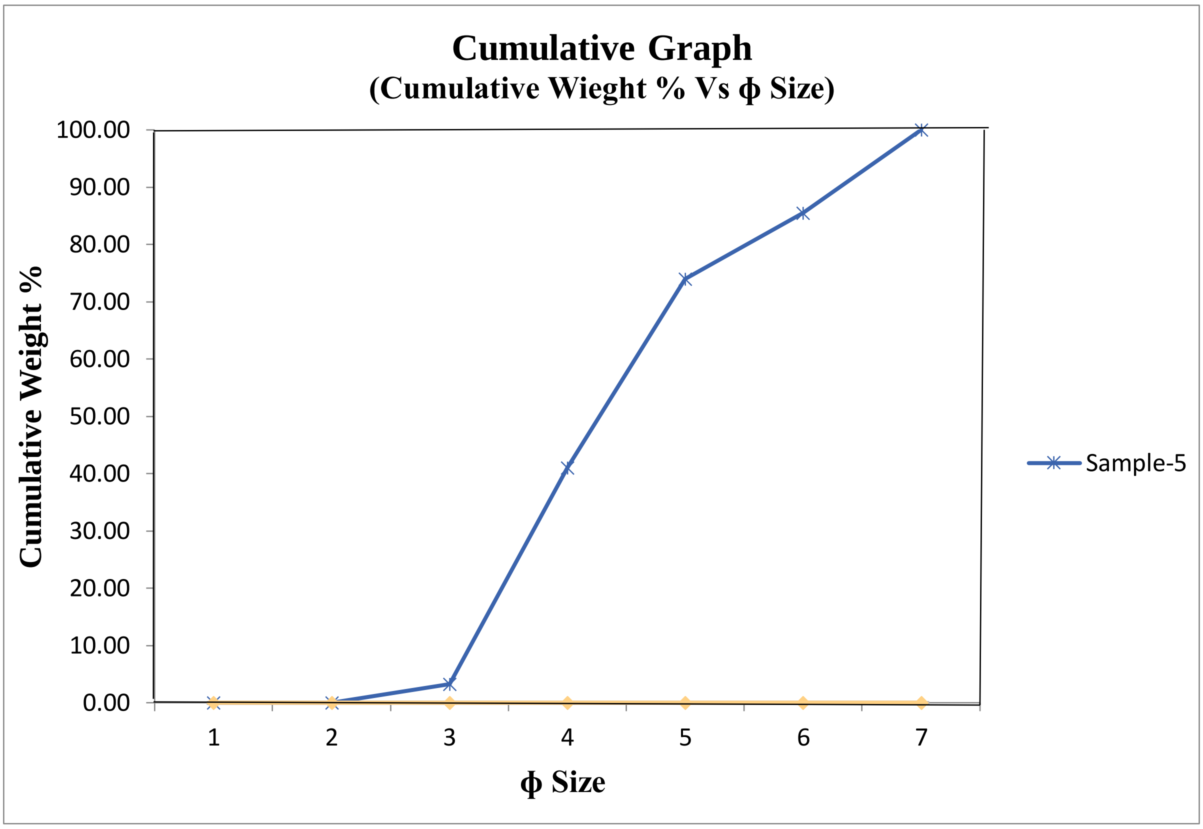
Type			Result	Comments
Graphic Mean	5.55	3.00	**1.85**	Medium Sand
Graphic Standard Deviation	0.33	0.42	**0.75**	Moderately Sorted
Graphic Skewness	0.12	0.21	**0.33**	Very Fine Skewed
Kurtosis	2.80	2.07	**1.35**	Leptokurtic

Sample No : 23
Date :
Section :
Location :
Rock type/ Facies :
Rock Unit :

Table 08: Different Grain Size Analyses- 5

Mash Size (d) (mm)	ϕ Size (log 2d)	Raw Data weight (gm)	Weight Percentage	Cumulative Weight Percentage
2	-1	0.00	0.00	**0.00**
1	0	0.06	0.06	**0.06**
0.5	1.0	3.17	3.17	**3.23**
0.25	2.0	37.772	37.77	**41.00**
0.125	3.0	32.991	32.99	**73.99**
0.063	4.0	11.54	11.54	**85.53**
Pan	4.25-14	14.473	14.47	**100.00**
	Total=	**100.00**	**100.00**	





Input ϕ (Phi) value from the graph paper

Scale	Value	Scale	Value
ϕ_{05}=	**1.10**	ϕ_{75}=	**3.10**
ϕ_{16}=	**1.45**	ϕ_{84}=	**3.80**
ϕ_{25}=	**1.65**	ϕ_{95}=	**5.05**
ϕ_{50}=	**2.25**		

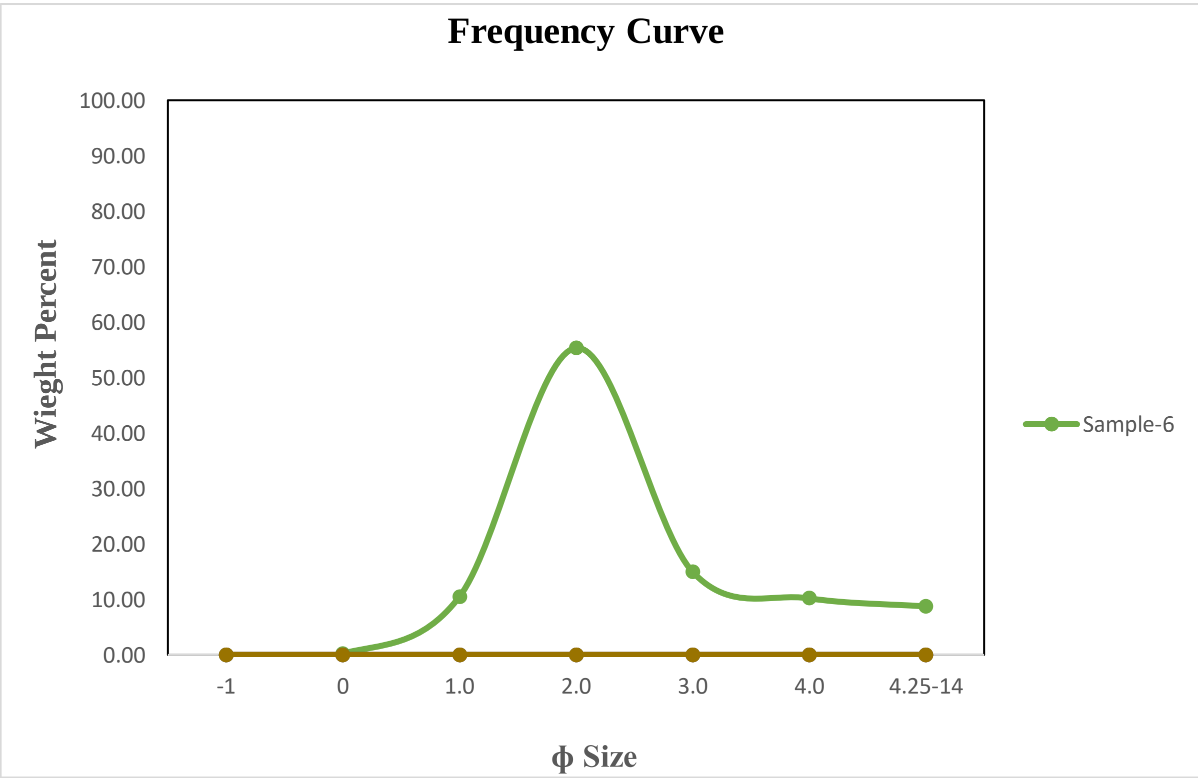
Result

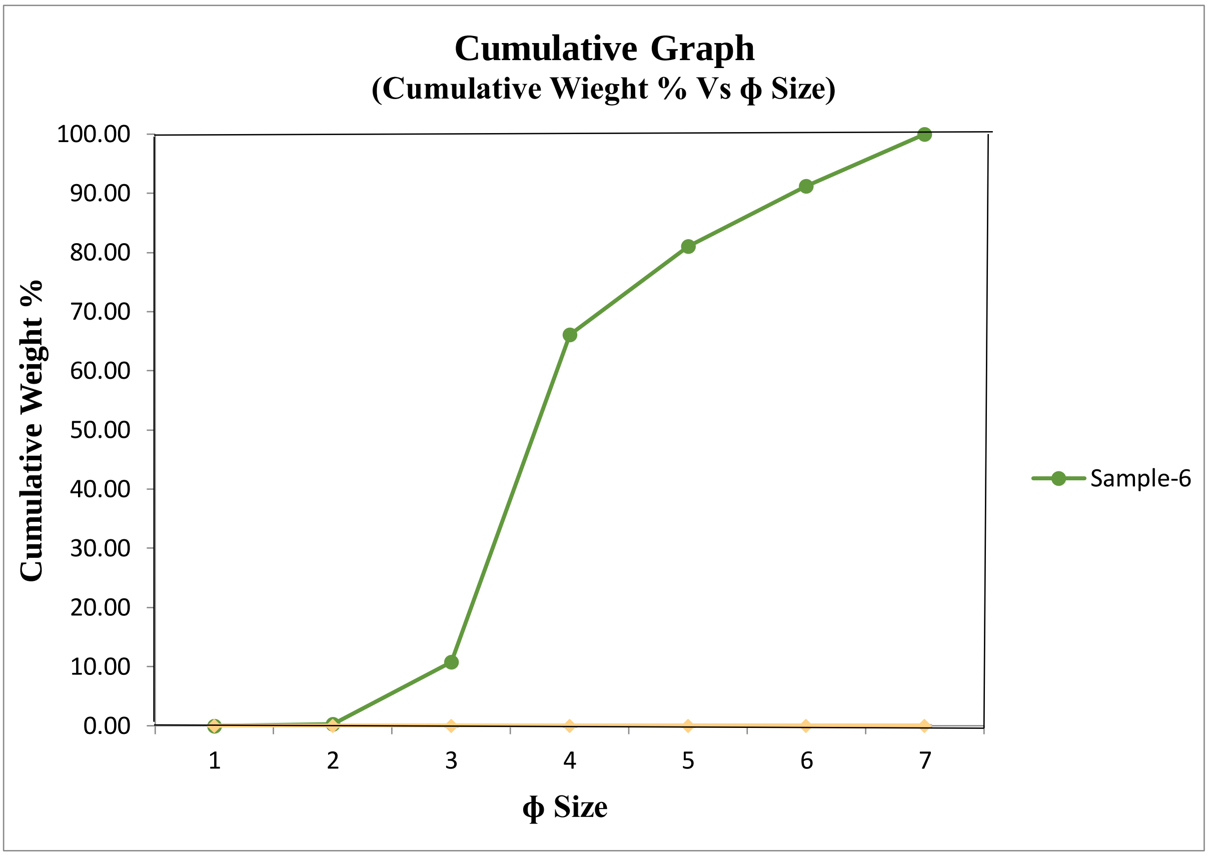
Type			Result	Comments
Graphic Mean	7.50	3.00	**2.50**	Fine Sand
Graphic Standard Deviation	0.59	0.60	**1.19**	Poorly Sorted
Graphic Skewness	0.16	0.21	**0.37**	Very Fine Skewed
Kurtosis	3.95	3.54	**1.12**	Leptokurtic

Sample No : 25
Date :
Section :
Location :
Rock type/ Facies :
Rock Unit :

Table 09: Different Grain Size Analysis- 6

Mash Size (d) (mm)	ϕ Size (log 2d)	Raw Data weight (gm)	Weight Percentage	Cumulative Weight Percentage
2	-1	0.00	0.00	**0.00**
1	0	0.269	0.27	**0.27**
0.5	1.0	10.482	10.48	**10.75**
0.25	2.0	55.325	55.33	**66.08**
0.125	3.0	14.984	14.98	**81.06**
0.063	4.0	10.202	10.20	**91.26**
Pan	4.25-14	8.735	8.74	**100.00**
	Total=	**100.00**	**100.00**	





Input ϕ (Phi) value from the graph paper

Scale	Value	Scale	Value
ϕ_{05}=	**0.85**	ϕ_{75}=	**2.45**
ϕ_{16}=	**1.15**	ϕ_{84}=	**3.25**
ϕ_{25}=	**1.35**	ϕ_{95}=	**4.35**
ϕ_{50}=	**1.75**		

Result

Type			Result	Comments
Graphic Mean	6.15	3.00	**2.05**	Fine Sand
Graphic Standard Deviation	0.53	0.53	**1.06**	Poorly Sorted
Graphic Skewness	0.21	0.24	**0.46**	Very Fine Skewed
Kurtosis	3.50	2.68	**1.30**	Leptokurtic

4.5 Description of Depositional Environment

In geology, depositional environment or sedimentary environment describes the combination of physical, chemical and biological processes associated with the deposition of a particular type of sediment and, therefore, the rock types that will be formed after lithification, if the sediment is preserved in the rock record. The exposed area that have been studied reflects a fluctuating environment ranging from fluviatile to shallow marine condition. The investigated area has been divided into four rock units and these are:

1. Nodular Bluish Gray Shale (Unit A)
2. Alteration of Sandstone and Shale (Unit B)
3. Crudely Bedded Yellowish Brown Sandstone (Unit C)
4. Loose Yellowish Brown Sandstone (Unit D)

Unit A was deposited over the underlying rocks after the second Himalayan orogenic movement (Krishnan, 1980). Shale and silty shale have been found in this region, which indicates that deposition has happened in a condition of changing depth of sea. Changing depth is due to receding and returning of sea and vast thickness of constant supply of the sediments of mainly silt and clay size (Muminullah, 1978). Presence of shale in this unit indicates that the rock is deposited under calm and quiet environment and the depositional environment may be shallow marine.

Analysis of the rocks of Unit B suggests that the rocks were deposited in deltaic environment. Furthermore, by analyzing the rocks of Unit C it was deciphered that the depositional environment is fluvial. Unit D contains clay gall which indicates its fluviatile depositional environment. The presence of pebble, cobble in this unit indicates nearer source area. Furthermore, the presence of mica suggests that, it is the youngest unit. Yellowish brown color and iron incrustation of this sediments is the indicator of intense weathering. The coarse grained sandstone was deposited at marine regressive phase at high energy fluviatile condition.

Chapter

05

Stratigraphy and Correlation

19. Stratigraphy of the Area

20. Correlation with Regional Stratigraphy

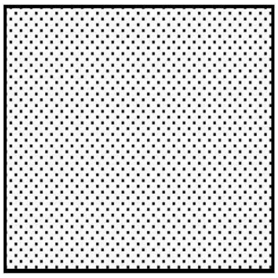
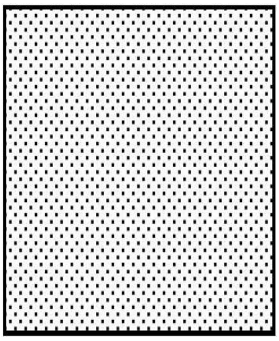
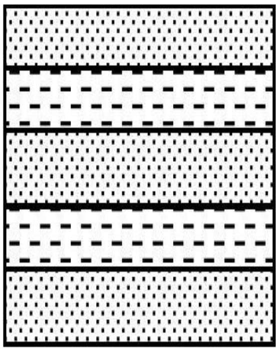
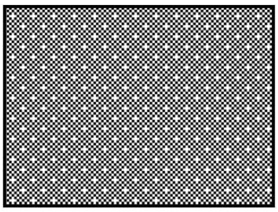
Chapter 5
Stratigraphy and Correlation

5.1 Stratigraphy of the Area

Stratigraphy is the study of stratified rocks which deals with original succession and age relation of rock state, distribution, and lithologic correspondence, fossil content and geochemical properties of strata. The main principle of stratigraphy is based upon sedimentary petrology and the basic principle of stratigraphy (Dunber and Rodgers, 1957). The Rangamati-Chittagong road cut section is characterized by several types of rock that are exposed along both sides of the road. By observing the rock types of the investigated area thoroughly, four rock units were found. They are as follows:

- Unit-A: Nodular Bluish Gray Shale (Oldest)
- Unit-B: Alternation of Sandstone and Shale
- Unit-C: Crudely Bedded YB Sandstone
- Unit-D: Loose Yellowish Brown Sandstone (Youngest)

Table 10: Stratigraphy of the observed area

Possible age	Stratigraphic Unit	Major Rock Types	Description	Symbol
Youngest	Unit-D	Loose Yellowish Brown Sandstone	Exhibiting yellowish brown color, medium to coarse grained sand sized particles, massive structured, highly permeable and friable, ferruginous cementing materials.	
	Unit-C	Crudely Bedded Yellowish Brown Sandstone	Brownish colored, composed of medium to coarse grained sand sized particles, crudely bedded, ferruginous cementing material. Thin layer of clay and clay galls are also present.	
	Unit-B	Alternation of Sandstone and Shale	Sandstone is yellowish brown to brownish in color, medium to fine grained, ferruginous cementing material. Shale is grayish colored, fissile nature, argillaceous cementing material.	
Oldest	Unit-A	Nodular Bluish Gray Shale	Bluish gray colored, composed of fine grained clay sized particles, shows nodular structure.	

5.1 Correlation with Regional Stratigraphy

Correlation of the rock formation of different regions to the regional strata is an important part of Stratigraphy. Correlation means the process by which stratigraphy specialists' attempts to determine the mutual time relations of a local section (Dunber and Rodgers, 1957)

Lithology and Stratigraphy are the possible means to the correlation of the studied area comparing the rock types of the surveyed area with that of Assam by vertical and horizontal cross section. Our investigated area, which lies on the eastern folded belt of Bengal Basin, was developed as the South extension of Assam Himalaya in the Mio-Pliocene age. The stratigraphy of Assam has been well established.

Table 11: Correlation between rock units of Ghagra- Rangamati road cut section and Assam, India.

Ghagra- Rangamati Road Cut Section			**Stratigraphy of Assam**			**Probable age according to Reimann, 1993**
Formation name	Rock Unit	Lithology	Group	Formation	Lithology	
Loose Yellowish Brown Sandstone	D	Exhibiting yellowish brown color, medium to coarse grained sand sized particles, massive structured, highly permeable and friable, ferruginous cementing materials.		Dupi Tila	Gray to Yellowish claystone, sandstone, siltstone etc.	Pleistocene
?	?	?	Tipam	Girujan Clay	Unconsolidated claystone, silty shale and sandstone with calcareous concretion.	Upper Pliocene

Crudely Bedded YB Sandstone	C	Brownish colored, composed of medium to coarse grained sand sized particles, crudely bedded, ferruginous cementing material. Thin layer of clay and clay galls are also present.		Tipam Sandstone	Yellowish to Brown sandstone and very subordinate shale.	Pliocene
Alternation of Sandstone and Shale	B	Sandstone is yellowish brown to brownish in color, medium to fine grained, ferruginous cementing material. Shale is grayish colored, fissile nature, argillaceous cementing material.	Surma	Bokabil	Alternation of siltstone and shale with calcareous band.	Upper Miocene
Nodular Bluish Gray Shale	A	Bluish gray colored, composed of fine grained clay sized particles, shows nodular structure.		Bhuban	Siltstone, silty shale, sandy shale and sand stone.	Lower Miocene
?	?	?	Barail	Barail	Sandstone with shale, very fine grained sand, poorly sorted, containing heavy mineral.	Oligocene

Chapter 06

Structural Analysis

Chapter 6
Structural Analysis

6.1 Major Structure

6.1.1 Fold

Folds are the waves of undulation found in the rock unit of the earth surface that forms in response to directional forces (Billings M.P., 1986). Force may be horizontal or tangential towards a common point or plain from opposite direction.

Based on our observation the first and foremost major structure that we observed and analyzed is an anticline, known as the "Sitapahar Anticline". Our observation suggests that, Sitapahar anticline is an asymmetric anticline. The western limb of the anticline being steeper than the eastern limb indicates its asymmetric nature. The western limb of the anticline is interrupted by a major fault which strikes almost parallel to the axis of the anticline. The axis of the fold is running in NNW-SSE direction parallel to the general trend of the regional strike.

It lies in the east of the Patiya and the west of the Gilasari and the Belasari structures (Fig). On the north of the Sitapahar anticline, Changotaung anticline is situated while bandarban anticline is located on the south. The Sitapahar anticline is a N20°W-S20°E trending structure plunging 6° in S18°E. The structure is about 40 km in length. Its steeper western flank is overturned in some places (Geological Structure, 2015).

The fold is evidenced by:

1. The measured attitude of the rock strata suggests that the beds are dipping in opposite direction from a place that represents an imaginary line.
2. The observed Nodular Bluish Gray Shale (Unit-A) was found in the axial region and it is oldest rock unit of the analyzed phenomena. This observation corroborates our claim that, the phenomena is an anticline.
3. The length of the eastern flank being less than the length of the western flank suggests that the anticline is asymmetric.

6.1.1.1 Structural Interpretation of the Fold

It is possible to interpret the overall structural sequence of Sitapahar Anticline by the implementation of the data acquired, in any Stereonet software. For the interpretation of the structural trend of the Sitapahar anticline such Stereonet software is being used and observed data are then plotted on an equal area stereonet. Steps of the analysis are as following:

a. Western Flank

Attitude of bedding planes taken: 13
Mean Vector: Trend-75, Plunge: 46

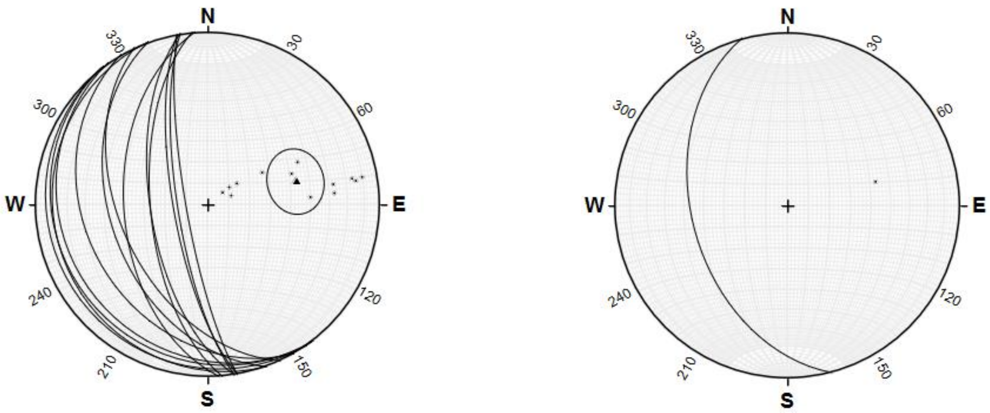


Fig 3: Great Circle and Pole Point for Western Flank

b. Eastern Flank

Attitude of bedding planes taken: 11
Mean Vector: Trend- 236, Plunge: 42

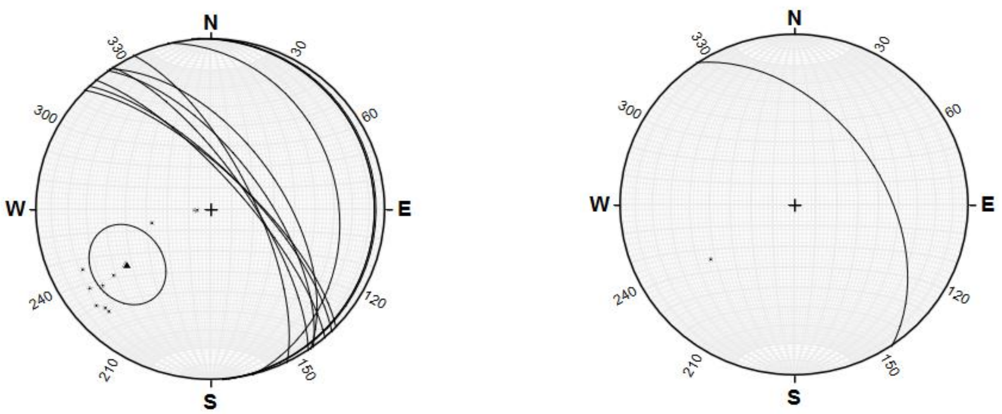


Fig 4: Great Circle and Pole Point for Eastern Flank

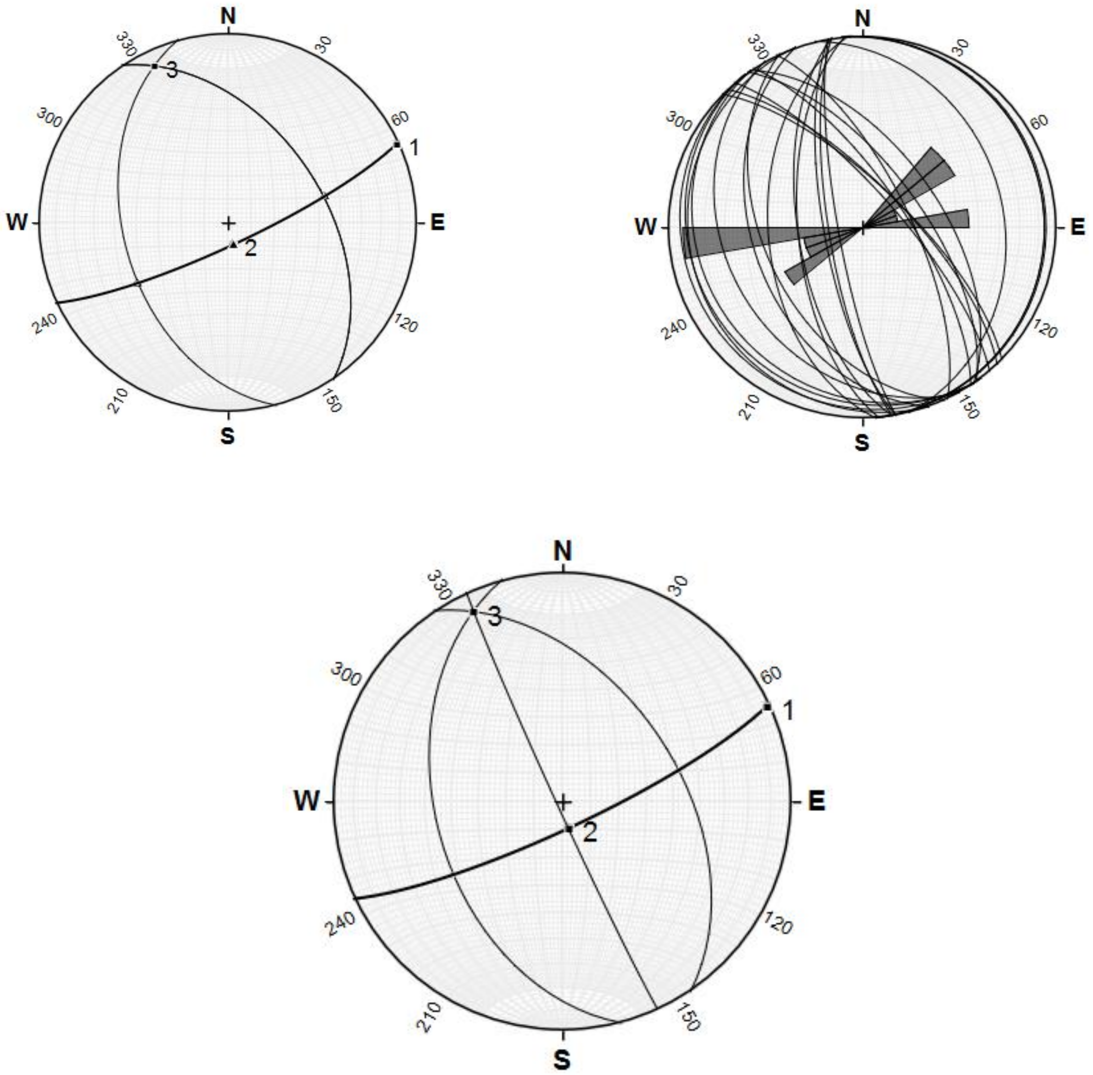


Fig 5: a) Intersection of the two limbs (335/10), b) Rose Diagram of both flanks

c) Attitude of Sitapahar Anticline (Strike 155.36, D.A: 87.96)

C. Fold Symmetry

Folds can be termed as symmetrical and asymmetrical based on the length of both limbs of the fold. If a fold have limbs of relative equal length, it can be termed as symmetrical. Otherwise, in case of distinct limb lengths, it is called asymmetrical. Asymmetrical folds generally have an axis at an angle to the original unfolded surface they formed on. Thus, from the above observation, it can be said that the fold is an Asymmetrical Anticlinal fold.

6.1.2 Fault

Faults are planar fracture or discontinuity in a volume of rock across which there has been significant displacement as a result of rock-mass movements. In this fieldwork two major faults are observed:

i. Longitudinal fault (thrust and/or reverse fault on the both flank) and
ii. Back thrust fault (eastern flank)

In the investigated area on the eastern flank of the anticline these faults are roughly N-S trending. This is more or less parallel to the axis of the structure.

The fault is evidenced by:

1. Abrupt change in dip amount.
2. Presence of opposite dip direction within short distances.
3. Visible displacement of layers.
4. Abruptly change in topography.

6.2 Minor Structure

6.2.1 Fold

In this fieldwork some minor folds are found. They are mainly parasitic fold drag fold and kink band fold.

1. **Parasitic Fold:** Fold of small wavelength and amplitude which usually occurs in a systematic form superimposed on folds of larger wavelength. Parasitic folds usually show typical S and Z asymmetric profiles on their limbs and M profiles in the hinge regions. In this observed area Z-fold has been found, which is long- short-long in shape. Generally is type of parasitic folds are found in clockwise respect to long limb, mostly on left flank. But in this area, this folds are found in right flank which indicate there’s a small scale fault.

2. **Drag Fold:** A minor fold, usually one of a series, formed in an incompetent bed lying between more competent beds, produced by movement of the competent beds in opposite directions relative to one another. Drag folds may also develop beneath a thrust sheet.

6.2.2 Joint

Joint is a fracture along which no appreciable movement has been occurred. Although they can occur singly, they most frequently occur as joint sets and systems. A *joint set* is a family of parallel, evenly spaced joints and *joint system* consists of two or more intersecting joint sets. In this study following types of joint sets are observed mainly:

1. **Parallel Joint:** Joints that are parallel to the bedding planes in a sedimentary rocks are called Parallel joint.
2. **Oblique Joint:** Joints which run in a direction that lies between the strikes and dip direction of the rock beds, are called Oblique Joints.

6.2.3 Fault

In this fieldwork some minor faults are observed. Among them antithetic fault is specially mentioned.

1. **Antithetic Fault**: Antithetic fault is a minor, secondary fault, usually one of a set, whose sense of displacement is opposite to its associated major and synthetic faults.
2. **Thrust Fault:** A thrust fault is a break in the Earth's crust, across which older rocks are pushed above younger rocks.

6.2.4 Cleavage

Cleavage is a type of secondary foliation that occurs in finer grain sedimentary rock.in this area cleavage plane is observed.

6.2.3 Slumping

A slump is a form of mass wasting that occurs when a coherent mass of loosely consolidated materials or a rock layer moves a short distance down a slope. Movement is characterized by sliding along a concave-upward or planar surface. Causes of slumping include earthquake shocks, thorough wetting, freezing and thawing, undercutting, and loading of a slope. In this area slumping structures are also observed.

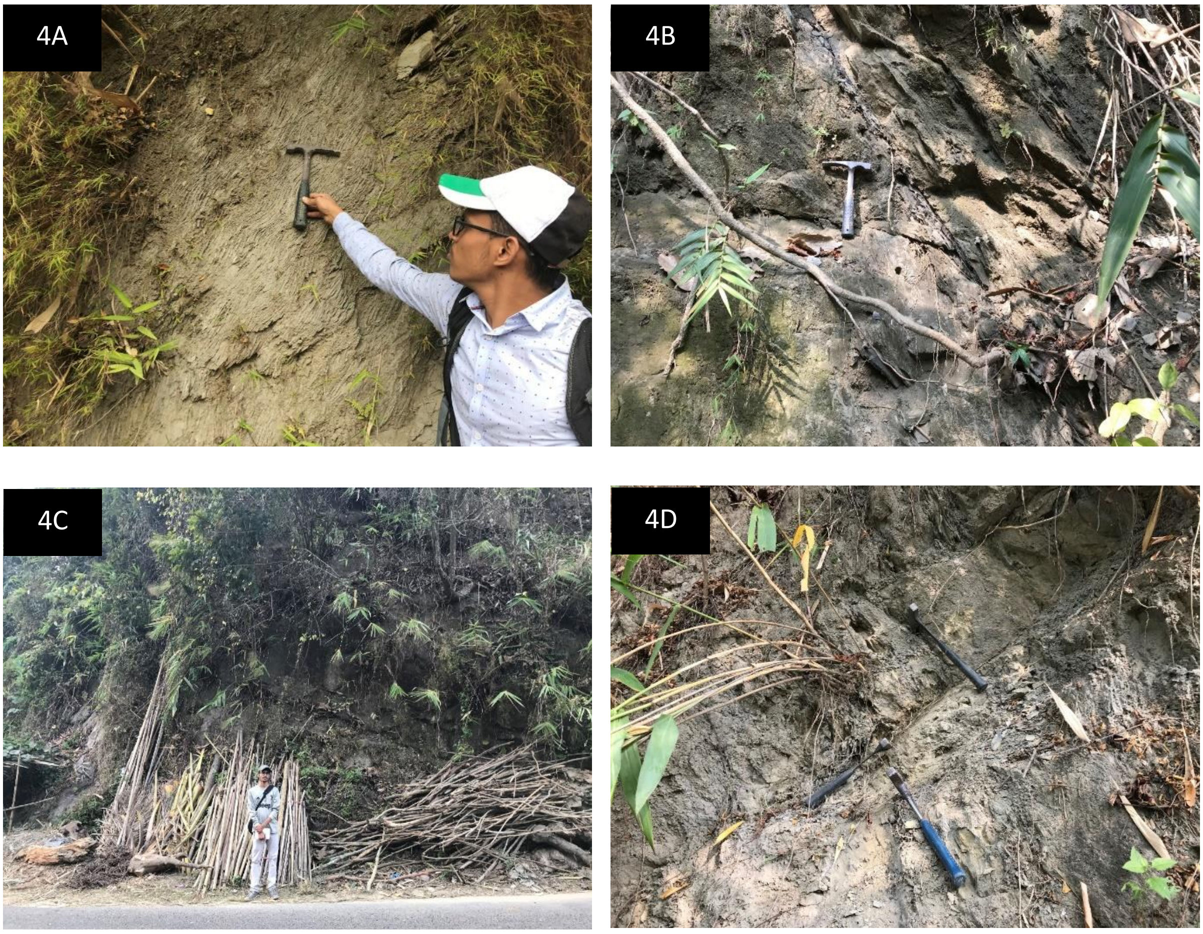


Plate 4: *Parasitic Fold (4A), Oblique Joint (4B), Antithetic Fault (4C), Thrust Fault (4D)*

Chapter 07

Economic Significance

Chapter 7
Economic Significance

The abundance of materials that are of immense economic significance, is simply inevitable. During the extensive fieldwork in the area, we found the abundant existence of sandstone, silt, shale, and mudstone etc., each of which is equally important both economically and geologically. The most economically important materials and their significances are described below:

- **Constructional Purpose:** Among the observed rock types, mudstone and silt are used especially as constructional material in building, industry or any type of constructional site.
- **Glass Industries:** The area has colossal amount of high grade sandstone which is of vital importance for glass industries and manufacturers.
- **Source of Hydro-carbon:** The investigated area (Sitapahar Anticline) is considered as highly prospective for hydrocarbon exploration. The prospect of hydrocarbon occurrences of the area requires some points such as source rock, reservoir rock, trap and timely migration and thermal maturity. The silty shale of the oldest unit shows some organic content that may be considered as the source of hydrocarbon generation.
- **Use of pebble, cobble and gravels:** These coarser grained sedimentary rocks are used in railway, highway, and bridge construction. In addition, these are used as grinding or frictional element in many industries.
- **Hydroelectric power generation:** Kaptai Lake is one of the biggest lakes of Bangladesh. This lake plays a very important role in the economy of this area. Due to excessive velocity and amount of water, this lake could be used as hydroelectric power generation source.

Chapter 08

Conclusion

Chapter 8
Conclusion

The investigated area is a hilly region with the presence of irregular topographical features and high altitude hillocks. It is an asymmetric anticline, associated with its gently dipping eastern flank and steeper western flank. The purpose of this field trip was to appreciate the sedimentology, structures, tectonic setting, and depositional environment of the area and to construct a general stratigraphy of the investigated area which was later correlated with the well-established regional structure. This field report also gives an overview on the economically significant zones, structures and rock types.

The observed Sitapahar anticline, locating between Changotaung anticline on the north and Bandarban anticline on the south, is a region of irregular topography with the general NNW-SSE trend. From geological point of view, it is a tectonically disturbed zone, giving rise to major faults in the associated areas. In each flank, two prominent thrust fault were identified.

The outcrops are generally poorly developed or already eroded out due to natural processes and anthropogenic activities. Yet, we managed to investigate enough exposures and acquire adequate information to analyze and interpret the rock formations of the area and to construct a stratigraphic sequence consisting of four distinct stratigraphic units based on the interpreted data. The four major stratigraphic units are, from oldest to youngest, Unit-A, Unit-B, Unit-C, and Unit-D. The major rock types observed in these formations are Yellowish Brown Sandstone, Crudely Bedded YB Sandstone, Bluish Gray Shale, Silty Shale, and Silty Shale while some of the major structures are Nodular Structure, Flaser Bedding, Lenticular Bedding, Wavy Bedding, Clay Gall etc. These major stratigraphic units were later correlated with the stratigraphy of Assam, on the basis of lithology, sedimentary sequences. Based on this observation, it can be concluded that, the investigated area consists of four major stratigraphic formations. These are, from oldest to youngest, Bhuban, Boka Bil, Tipam, and Dupi Tila, aged between Miocene to Plio-Pleistocene.

By observing the color, texture, grain compaction, and structure of these rock units, it is assumed that, the depositional environment of Unit-A, Unit-B, Unit-C, and Unit-D is Marine, Deltaic, Fluvial and Continental Fluviatile respectively.

Furthermore, based on our observation, the investigated area is economically significant for the dependence of construction industries on the rocks found in this area, and for the possibility of the presence of hydro carbons. Thus, it can be said that, proper investigation in mandatory for the detection of oil and gas in this area.

Finally, it can also be added that, Sitapahar anticline is an excellent place for a Sedimentologist and for a Structural Geologist, to further investigate the area extensively.

References