A GEOLOGICAL FIELD REPORT ON JAINTIAPUR DISTRICT, SYLHET, BANGLADESH.

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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. Nine lithostratigraphic units were identified upon observing these rocks. These units from Oldest to Youngest are Unit-A (Limestone), Unit-B (Shale), Unit-C (Pinkish Sandstone), Unit-D (Sandy to Silty Shale), Unit-E (Alternation of Sandstone and Shale), Unit-F (Ferruginous Sandstone), UnitG (Mottled Clay), Unit-H (Variegated Colored Sandstone) and Unit-I (Matrix Supported Gravel Bed). 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, DupiTila and Dihing 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.

Contents

Chapter One

1.1 Introduction

The Sylhet trough of the Bengal Basin is located in eastern part of Indian subcontinent. The trough occupies a vital geographic position at the junction of three interacting plates, namely, The Greater India, Burmese and Tibetan Plates (figure 1 a) 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 plate and Tibetan plate (Alam, 1989) and later is linked with the uplift of the Shillong plateau (ref.).

A significant part of the Sylhet trough within the Bengal Basin is mostly covered by young alluvial cover. Limited outcropping rocks are only found in the hilly areas that occupy mass of the eastern and northeastern parts of the country (i.e., Bangladesh). A continuous Cenozoic stratigraphy of the Sylhet Trough is only exposed in the Jaintiapur area within the Sylhet district, Bangladesh (within the latitude of 25°05′N to 25°12′N and the longitude of 92°01’E to 92°12′E.) (figure 2). Unfortunately, stratigraphy of the Sylhet Trough or Bengal Basin is not well stablished and has been correlated with the stratigraphy of Assam region (Evans, 1932) which has different tectonic history.

Thus, the Jaintiapur area carries a significant value in understanding the stratigraphy, tectonics and basin-fill history of Bengal Basin. This report deals mainly with the result of field observations and samples collection from different section of Jaintiapur and adjoining area.

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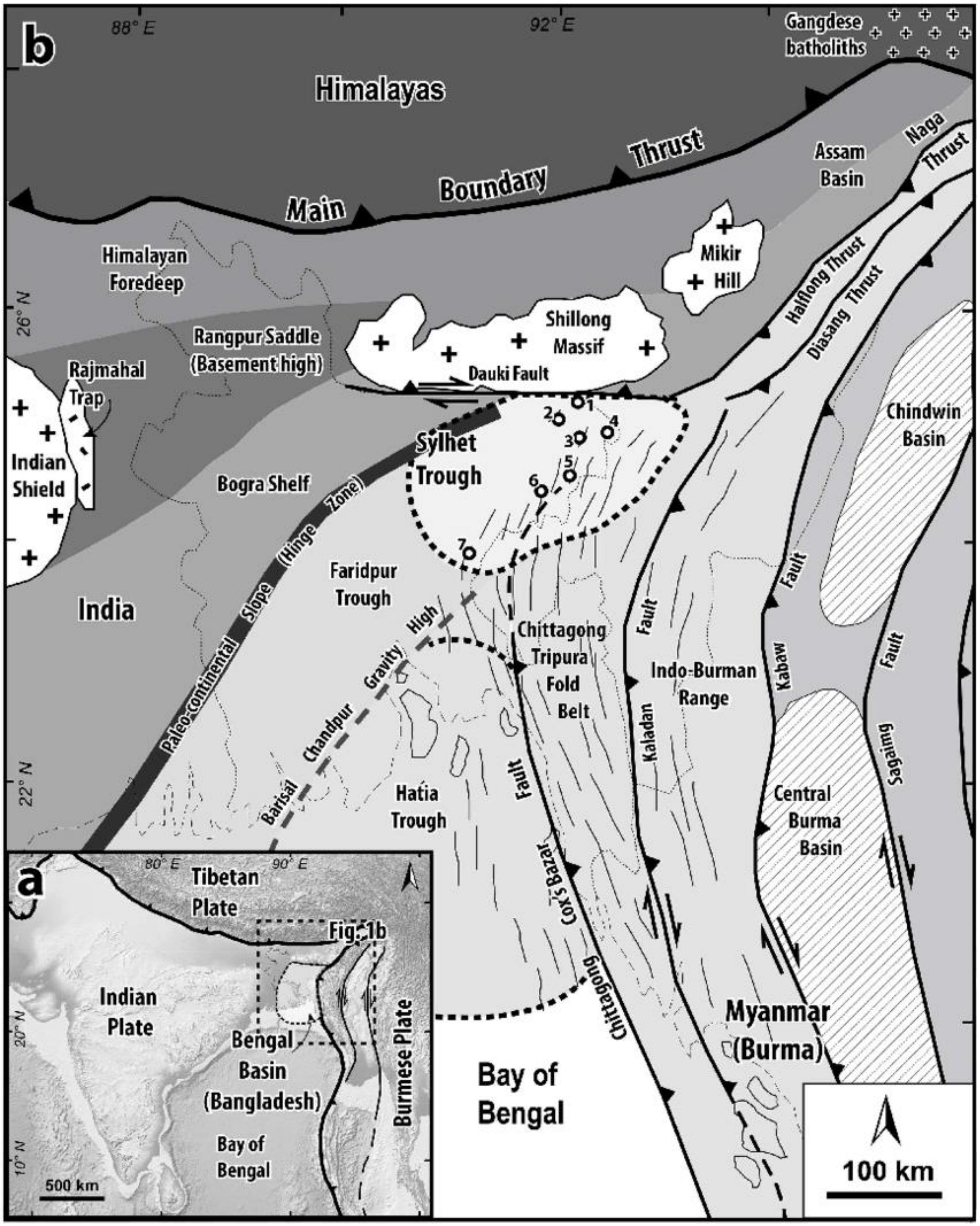
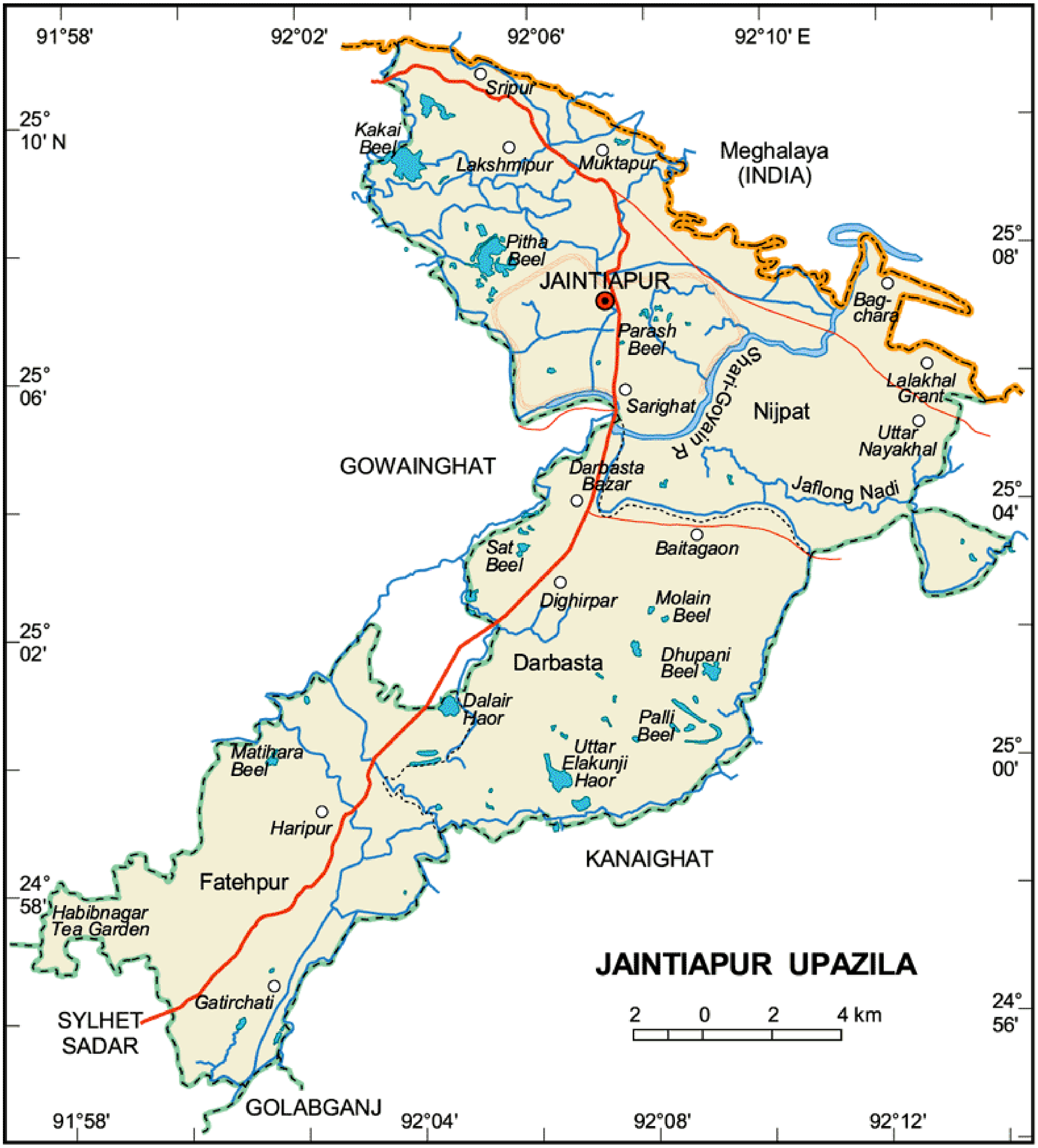


Map 1. a. Location of Bengal Basin in the context of the Indian, Tibetan and Burmese plates. **b.** Map shows tectonic elements of the Bengal Basin and location of the studied area (modified after Alam et al., 2003



Map 2: Location Map of Jaintiapur Upazil

1.2 Accessibility

1.2.1 Tropography

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 vallies 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

1.2.2 Drainage

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.

Piang River is the important tributary of Dauki. The Hari River is originated from Khashi-Jaintia hills, flows southward and enters into Bangladesh near Bagchara. The Ragapani and Nayagang are important tributaries of Hari River flowing in the central portion of the area. The streams are both structurally and lithologically controlled and dendritic in pattern. Major streams are relatively fewer and are of perennial type but minor rivers are large in number and intermittent in type. Many Khal, nala and bil are also present.

1.2.3 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 felt in Jaintiapur 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 average annual rainfall (according to M.A.M KHAN) is more than 150 inches in the area.

1.2.4 Vegetation

The climatic condition of this investigated area is tropical to sub-tropical. A lot of precipitation and sufficient heat favor the luxuriant growth of evergreen forest. 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 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 lowlying areas are used for Boro cutivation. 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, banana are also grown here. Other seasonal crops like tobacco, oilseeds and vegetables such as pumpkins, beams are also grown in this area.

1.2.5 Population

The total population of this area is about 98.370 (source U.N.O. Office, Jaintiapur) and the Jaintiapur Upzilla covers an area of 99.98 sq miles. The lifestyle of these people are not so easy, they are living along the foot of the hills and in plain land. These people are socially and economically undeveloped. They have no adequate facilities of civilization. Their education rate is 21%. Most of the people depend on agriculture. Other depends on gardening, fishing, teaching, weaving etc, some of them are engaged in gravel and sandstone quarrying, trade and commerce. A little percentage of the population is employed in government services. Most of the people are Muslims, some are Hindus, Christian and Buddhists. The migratory Khashia and Shaotalis are the tribal people. In the tea garden there are some Oriyas, Nunayas and other people from Chotto Nagpur plateau, India who brought before 1947 and settled here. The Khashias have their own language and mainly Christian. They live in a group of 10-30 families. They work hard and the women work with men.

1.4 Previous Investigation

A large number of exploration works and drilling has been carried out since 1933 in Sylhet. Burma Oil Company had been the pioneer.

A geological study of the eastern and northeastern part of the Surma Basin has been carried out by M. A. Maroof Khan of Geological Survey of Bangladesh during 1964-66. J.F Holtrop and J Keizer published a correlation of Surma Basin wells in 1960. K.M. Wallid

and Dr.Reimann carried out Palynostratigsaphic analyses of Oligocene outcrop samples. M. Hoque studied the development of the Surma Basin and its relation of Hydrocarbon accumulation.

Khan published a geologic map of one-inch equals to two miles scale, which embraced the whole Tertiary succession of the area.

Haque (1982) developed a scheme of palynologic zone of a Cenozoic succession in the Surma Basin. He also reviewed the exposed and subsurface stratigraphy of the Surma Basin.

D. K. Guha also investigated the area. Students and teachers of geology study the area every year.

1.5 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.

Fieldwork was done for the following work

1. Producing Geological map.
2. Identification of lithology.
3. Identification Sedimentary structures.
4. Construction of Stratigraphic Column.
5. Sampling.
6. Grain size analysis.
7. Study of major structures and other structural features.

1.6 Methodology and Equipment

For geological field mapping, traversing has been used. This technique involves in measuring distance and identifying position in a map by measuring distance by pacing.

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

Mappable lithostratigraphic units have been classified based on lithology (rock assemblages). Stratigraphic correlation among different sections of the area has been done.

In order to understand the structural geology of the area, structural measurements (dip and strike) have been taken and immediately plotted on the map. Geological cross-sections have constructed to understand the surface geology.

Finally, all the observations have been used to synthesize a coherent geological history of the area.

Equipments	**Uses**
Base Map	Used to locate observed information on the base map.
Clinometer	Used to measure attitude of the bed.
Note book	Used to note down data and other features.
Haversack	Used to carry all the equipments.
Clip board	Used to hold the base map in proper position and took support for necessary drawing.
Pocket lens	Used to observed the texture of rocks and sediments.
Dilute HCl	Used to identify the cementing material of the rocks whether it is calcareous or not.
Measuring tape	Used for measuring the distance among the different types of Sedimentary strata.
Hammer	Used to collect sample and find out the other sedimentary structure.
G.P. S	Used to measure the latitude and longitude of any place at any Time.
Camera	Used to take photographs of important features.
Sunglass	Used to protect eyes from dust and from heavy sunlight.
Sample Bag	Used to collect sample.
Permanent marker pen, tags and rubber band	Used to write down the information about the sample on the bag for laboratory analysis.
First aid box	Used to protect from any initial infection

CHAPTER TWO

2.1 Dauki river section (L1 to L4): In Dauki river section we mainly found Nummulitic limestione which is yellowish color, hardly compacted. These are mainly clastic sediment. This area belongs to the Dauki fault zone. Beds are dipping towards the south.

Figure:- Showing Limestone facies found in Bollaghat.

2.2 Jaintapur Tamabil Road Cut section: TamaBil is about 60 km northeast from Sylhet and Jaflong is 45 km from TamaBil. In this area we found alteration of sandy and silty shale and pinkish sandstone. And laterite bed also found which is local unconformity. A series of fault is found.

2.3 Noyagang Komolabari Gourisanker: In this area, we found pinkish sandstone and silty to sandy shale. Interformational laterite bed is also found. In last location in this section, we found Dihing formation. Beside this, we also found microfault.

2.4 Sari River section: The Shari-Goyain enters Bangladesh through northern part of Jaintiapur upazila in Sylhet district. In this area we found sandy or silty shale, sand shale alteration and yellowish-brown sandstone. Beside this wavy, lenticular, flaser sedimentary structure also found. Mega cross bedding, boudinage, brunching structure are special features in this section.

2.5 Dupigaon section: The type area of the Dupi Tila Formation, named for a sandstone cropping out near a village called “Dupigaon” in the Sylhet District. Varigated colour dupitila sandstone consists of upper clay layer and lower sand layer which is found in last location.

Fig:- Showing verigetad color sandstone found in Dupigaon Section

Table:- Showing the description of all sections in a nutshell

Location no.	Attitude	Rock type	Sedimentary Structure	Lithology
L-1	Dip direction:135 Dip amount:39	Limestone		Nummulitic limestone
L-2	Dip direction: Dip amount:	Shale	Fissility	
L-3	Dip direction: S6E Dip amount: 16	Pinkish sandstone	Lamination, thick to thin bedded	Laterite, iron incrustation present
L-4	Dip direction: 130 Dip amount: 82	Pinkish sandstone		Hard and compact, fine to medium grained
L-5	Dip direction: N30W Dip amount: 19	Pinkish sandstone		Sandstone, sandyshale, siltyshale alteration
L-6	Dip direction: Dip amount:	Pinkish sandstone		Whitish sand and blakish clay present

L-7	Dip direction: N 22 W Dip amount: 10	Pinkish sandstone	Thickly bedded	Medium to fine grained
L-8	Dip direction: 178 Dip amount: 27	Pinkish sandstone	Thickly bedded	Medium to fine grained
L-9	Dip direction: Dip amount:	Pinkish sandstone		Laterite bed present
L-10	Dip direction: 196 Dip amount: 34	Pinkish sandstone		Clay galls and burrows present
L-11	Dip direction: 208 Dip amount: 49	Pinkish sandstone		
L-12	Dip direction: 178 Dip amount: 42	Pinkish sandstone		Medium to fine grained
L-13	Dip direction: Dip amount:	Sandyshale	Ripple cross lamination, wavy bedding	Intraformational conglomerate bed present
L-14	Dip direction: 186 Dip amount: 38	Sandyshale	Thinly bedded	Fine grained sand with few sandy to silty shale
L-15	Dip direction: 183 Dip amount: 37	Shale	Thinly bedded	Shale with sand lens
L-16	Dip direction: 184 Dip amount: 44	Shale	Thinly bedded	Shale with sand lens
L-17	Dip direction: Dip amount:			
L-18	Dip direction: 215 Dip amount: 46	Shale	Thickly bedded, nodular structure due to dragging, ripple cross	Large block of sst ,very fine silt present

			lamination present	
L-19	Dip direction: 203 Dip amount: 61	Fine sand to siltstone		Calcareous sst band present
L-20	Dip direction: 208 Dip amount: 50	Yelllowish brown sandstone	Wavy and flaser bedding	Medium to fine grain
L-21	Dip direction: 206 Dip amount: 49	Sand shale alteration	Trough cross bedding	UMS shale and yellowish brown sst
L-22	Dip direction: 204 Dip amount: 47	Yelllowish brown sandstone	Mega Cross bedding	Conglomerate bed present
L-23	Dip direction: 197 Dip amount: 71	Yelllowish brown sandstone	Concretion, planar stratification	Ferruginous sandstone
L-24	Dip direction: 182 Dip amount: 73	Yelllowish brown sandstone		Laterite
L-25	Dip direction: 198 Dip amount: 75	Yelllowish brown sandstone	Local unconformity, trough cross bedding	Conglomerate bed and clay galls present
L-26	Dip direction: 194 Dip amount: 75	Sandstone to siltstone, siltyshale		Ferruginous sandstone
L-27	Dip direction: Dip amount:	Clay	Massive structure	Mottling nature
L-28	Dip direction: 191 Dip amount:51	Sandstone	Mega trough cross bedding	Varigated color sandstone, coarse to medium grained, poorly sorted. Quartz and pebble present.
L-29	Dip direction: 179 Dip amount:84	Sandstone	Trough cross bedding	Varigated color sandstone, coarse to medium grained, poorly sorted.

L-30		Sandstone		Lower portion sandy and upper portion clayey.

2.6 Sedimentary structure

Sedimentary structures refer to the various features and arrangements found within sedimentary rocks. They provide valuable information about the processes by which sediments were deposited and subsequently transformed into rock. Sedimentary structures can be observed at different scales, ranging from microscopic to macroscopic.

In our studied area we found two types of sedimentary structures.

1.Primary Sedimentary structure

2.Secondary sedimentary structure

2.6.1 Primary sedimentary structure:

Planer bedding: Planar bedding is a common sedimentary structure where layers of sediment are deposited horizontally or with a minimal tilt. These layers are often parallel to each other and can be distinguished by variations in grain size, composition, color, or other sedimentary characteristics.

Planar bedding can occur in various depositional environments, such as lakes, rivers, deltas, and marine settings.

Tabular Cross bedding: Tabular cross-bedding is a type of sedimentary structure characterized by inclined layers or sets of layers within a larger sedimentary bed. Tabular cross-bedding typically forms in environments where wind or water currents are responsible for the transport and deposition of sediment. The cross-beds in tabular cross-bedding can exhibit different orientations and can range in size from a few centimeters to several meters in scale.

Fig:- Tabular cross bedding structure

Trough cross bedding: Trough cross-bedding is a type of sedimentary structure characterized by inclined layers or sets of layers within a larger sedimentary bed. The distinguishing feature of trough cross-bedding is that the inclined layers form elongated trough-shaped structures.

Fig:- Trough cross bedding structure.

Trough cross-bedding typically forms in environments where water currents or wind are responsible for the transport and deposition of sediment. The size of the troughs can vary from small-scale ripples to large-scale dunes, and the angle of inclination can vary depending on the strength and direction of the currents or winds involved in the deposition process.

Lamination: lamination refers to the presence of very thin, parallel layers or laminae within a sedimentary rock. These laminae are typically less than a centimeter thick and can be distinguished by variations in color, grain size, mineral composition, or other sedimentary characteristics.

Fig:- Showing Laminated bed

Flaser bedding: when mud streaks are present in sandstone then the structure is called flaser beeding

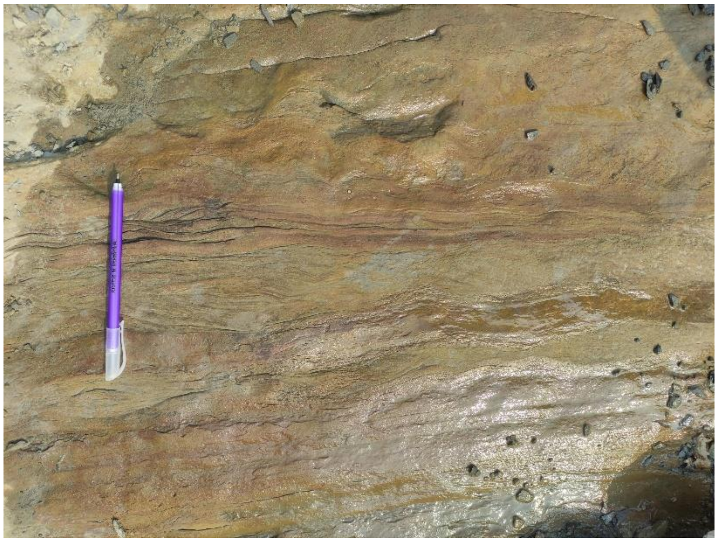


Fig:- Showing Flaser wavy bedding structure

Lenticular bedding: when sand lenses are present in clay or mud then the structure is called lenticular bedding.

Figure:- Showing Lenticular wavy bedding structure

Wavy: When mud and sand proportion is being equal then the structures are called wavy bedding (Fig), which indicate the fluctuations of energy condition. This are formed in the intertidal zone. (Lindholm, 1991)

Ripple cross lamination: Forms when deposition takes place during migration of current or wave ripple .

2.6.2 Secondary structure:

Boudinage structure: Boudinage is a geological term used to describe a specific type of structure that forms when a layer or vein of a more resistant rock material gets elongated and segmented within a less resistant surrounding rock. The formation of boudinage occurs due to the differential stress exerted on rocks during deformation. When rocks are subjected to extensional forces, the more competent or stronger layers may resist deformation more than the surrounding weaker layers. Location 21

Brunching structure: (Location 23) Due to fluid in the rock its look like vein. It is a deformational structure.

Flute mark structure: Flute marks, also known as flute casts or flute marks, are sedimentary structures commonly found in fine-grained sedimentary rocks such as sandstone, siltstone, or shale. Flute marks appear as elongated, streamlined depressions or troughs on the bedding surface of a sedimentary layer. They have a distinct asymmetric shape, with a gentle upstream or stoss side and a steep downstream or lee side. (Location 29)

Seismite (Flame structure): A seismite refers to a type of sedimentary rock or sedimentary structure that is formed as a direct result of seismic activity or earthquakes. Seismite deposits provide evidence of past earthquakes and can offer valuable insights into the history and behavior of seismic events. (Location 12)

Chapter Three-Sedimentology

Sedimentology is a scientific discipline that studies sediments and sedimentary rocks. It encompasses the processes of sediment transport, deposition, and diagenesis (the physical and chemical changes that occur in sediments after deposition). Sedimentology seeks to understand how sediments are formed, transported, and preserved and the environments in which they were deposited.

Sedimentology involves examining and interpreting sedimentary features, such as sedimentary structures (e.g., bedding, crossbedding, ripple marks) and textures (e.g., grain size, sorting, and roundness). These features provide clues about sediments' origin, transport, and depositional environment.

By studying sediments and sedimentary rocks, sedimentologists can reconstruct past environments, understand Earth's history, and interpret the geological processes that have shaped our planet. Sedimentology has applications in various fields, including petroleum geology, environmental geology, paleontology, and hydrogeology.

3.1 Facies Analysis

Sedimentary facies refers to distinct sedimentary deposits or rock units that share similar characteristics and can be distinguished from adjacent deposits based on their sedimentary features, composition, and fossil content. Sedimentary facies are defined by the combination of sedimentary processes, environments, and conditions under which the sediments were deposited.

Sedimentary facies represent a snapshot of a specific depositional environment at a particular time. It can provide insights into the paleoenvironmental conditions, such as the presence of a river, a beach, a deep-sea setting, or a desert, during the deposition of sediments.

Facies analysis involves identifying, describing, and interpreting different facies types within a sedimentary sequence. By studying sedimentary facies, geologists can reconstruct past environments, understand the spatial and temporal variations in sedimentation, and interpret the geological history of an area.

Facies can be characterized by various sedimentary features, including grain size, sediment composition, sedimentary structures (such as bedding, cross-bedding, ripple marks), fossil content, and geochemical signatures. These characteristics are used to differentiate one facies from another and interpret the deposition processes and conditions.

Sedimentary facies can transition laterally or vertically within a sedimentary basin, reflecting changes in environmental conditions, sediment supply, or sea-level fluctuations. By mapping and correlating facies across different locations, geologists can reconstruct the ancient geography and paleoenvironmental conditions of an area during a specific period.

Sedimentary facies analysis is essential in various fields of geology, including stratigraphy, sedimentology, paleontology, and reservoir characterization. It helps understand the distribution of sedimentary rocks, predict the occurrence of natural resources (such as oil and gas reservoirs), and reconstruct Earth's past environments and climate changes.

Facies is classified based on three characteristics:

- Lithofacies: Based on the lithology and physical aspects of rocks.
- Biofacies: Based on flora and fauna assemblage.
- Ichnofacies: Focuses on trace fossils of rocks.

Sedimentary lithofacies is a mappable subdivision of a stratigraphic unit that can be distinguished by its facies or lithology—the texture, mineralogy, grain size, and the depositional environment that produced depositional environment, depositional system, and stratigraphy. In our total observation, we found different types of sedimentary rocks. They are- Limestone, Sandstone, Shale, and Claystone dominantly. Based on lithology and sedimentary structures, we classify our studied area into several lithofacies They are described below:

Limestone Facies: Limestone facies is again subdivided into two sub-facies based on fossil content. These are Fossiliferous Limestone & Crystalline Limestone.

Fossiliferous Limestone: The rock unit is grayish to yellowish brown, fine to medium grain size, rugged and compact but relatively less than non-fossiliferous limestone, poorly porous. It gives enthusiasm with HCl, which indicates calcareous cementing material. It contains a vast assemblage of fossils, such as the benthic foraminifera (Numulites) index fossil, identified to the naked eye as white to grayish white. It is the lower part of the limestone unit, which indicate a relatively older age.

Crystalline Limestone: Grayish, fine to medium grain size, very hard and compact, thick-bedded, highly jointed and fractured, poorly porous, and shows calcareous cementing material. It is the upper part of Limestone unit, which indicate a relatively younger age. Brecciated limestone, which is reddish brown color, it is varied in size (2-3 mm to a few cm), also hard and compact. The slumping part of Fossiliferous and non-fossiliferous limestone has also been observed. Above the limestone bed, a gravel bed has been found that represents the erosional surface marking the upper limit of the unit.

Black shale facies: The rock is dark gray to black color, laminated with fissile nature, containing argillaceous cementing material, conchoidal fracture. Microfossil is present in this facies which we cannot identify in naked eye. This facies was organic matter rich.

Silty Shale facies: The rock is yellowish to dark gray, fine to medium-grained. Parallel lamination, micro cross lamination, lenticular, and bipolar trough cross-lamination in sedimentary structures are also observed. The facies has high organic content and cementing material is argillaceous

Siltstone Facies: The rock is gray, moderate to highly compacted, and it gives effervescence in contact with HCl.

Mudstone Facies: The rock is yellowish gray in color, hard and compact, argillaceous cementing material.

Laminated shale facies: The rock is gray in color, shows mostly fissile nature and argillaceous cementing material. We observed flaser, lenticular and wavy structure. Micro cross lamination was found within sand lenticel.

Sandy Shale facies: It is bluish gray in color, very fine to fine grained, moderately compacted, cementing material was argillaceous. Micro cross lamination was also observed here. It shows micro cross lamination. It contains sandstone, siltstone, mudstone in minor amount.

Claystone Facies: It is Bluish gray color, mottled nature, high organic content, plasticity medium to high. No specific structure is found. Kaolinite was found and it was white in color, hard and compact.

Grayish shale facies: We observed color variety in shale. It shows dark black to dark gray in color, because of variation of organic content. It shows low porosity and permeability. It shows nodular structure, parallel lamination. Cementing material is argillaceous. It contains trace fossil.

Massive pinkish sandstone: It is pink, yellowish to pinkish in color, fine to very fine in size, highly porous and permeable, shows ferruginous cementing material. It is dominantly massive sedimentary structure but occasionally parallel lamination, trough cross lamination, lesigan (post depositional structure) and Iron concretion are also present.

Massive grayish sandstone: The rock is gray in color, fine to medium grained size, moderately compacted, medium porosity and permeability, shows arenaceous cementing material. Dominantly massive sedimentary structure but occasionally lamination is found.

Microcross laminated sandstone: It is bluish gray in color, medium to fine in size, moderately to hardly compacted, medium porosity and permeability, siliceous cementing material, cross lamination, microcross lamination structures are present.

Yellowish brown sandstone facies: The rock is yellowish brown and gray color, fine to medium grain, poorly sorted, moderately compacted, high porosity and permeability, argillaceous and ferruginous cementing material, massive & planar cross bedding (lower), micro cross lamination and clay gall (upper) and petrified wood also found.

Lenticular bedded sandstone facies: The rock is yellowish brown to gray in color, lenticular bedded sandstone with thin flat sand lences.

Flaser bedded sandstone facies: The rock is light gray to brownish gray in color, fine to medium grained sandstone with flaser bedding. Wavy bedded sandstone facies: The rock is yellowish brown in color, moderately compacted with wavy nature.

Large scale trough cross bedded yellowish brown sandstone facies: The rock is yellowish brown color, fine to medium grained, sorting is well to moderate, sub-angular to sub rounded angularity, moderately compacted, shows high porosity and permeability, cementing materials are siliceous and ferruginous, trough scale cross bedding dominantly with parallel lamination ,planer cross bedding and trough cross bedding, call gall petrified wood very thin layer coal have been observed.

Variegated color sandstone facies: The rock is yellowish brown, brown, pink and gray color, fine grained, sorting is well to moderate, moderately compacted, shows high porosity and Page | 23 permeability, cementing materials are siliceous and ferruginous, massive structure, trough & planar cross bedding, iron incrustation, iron layer and flute marks are also present, cobble, pebble and occasional clay gall also found.

Parallel laminated Channel sandstone facies: It is gray, fine to medium grained, moderately compacted, highly porous and permeable, lamination and lag deposits are found. It contains organic and carbonaceous matter.

Calcareous sandstone facies: It is gray, thin to medium bedded, very hard and compact, and gives effervescence in contact with HCl, which indicates calcareous cementing materials.

Table 1 Summary of Lithofacies observed at Jaintiapur and its adjoining area

FACIES NAME	FACIES CODE	DESCRIPTION	INTERPRETATION
Limestone	L_b	Bedded Limestone, highly fossiliferous, Nummulitic fossil, non-clastic origin and some crystallinity, brecciated due to fault.	Sallow marine, non-clastic, shelf area precipitation.
Shale	Sh_l	Dark gray colored Shale, laminated and fossiliferous.	Calm and quiet environment, discontinuous suspended load deposits.
Sandstone with Gravel (Dihing)	S_g	Yellowish brown sandstone, coarse to very coarse grained, numerous gravel (pebble, cobble) sized particle present.	Continuous sand sedimentation, high energy bedload deposits.
Trough Cross Bedded Sandstone	S_t	Yellowish brown sandstone, fine to medium grained, poorly sorted, numerous pebble size clast and clay galls present, trough cross bedded.	Lower flow regime, migration of dune due to high energy.
Conglomerate	C_m	Dark brown colored, clast supported conglomerate, very hard and compact, sand size (medium to coarse) matrix, usually found above the erosional surface.	Erosion occurred at high energy condition and in low energy condition, gravel particle deposits. Erosional surface.
Ripple Cross Laminated Sandstone	S_r	Pinkish sandstone, fine to very fine grained, ripple cross laminated, sometimes, ripple cross lamination present.	Lower flow regime, migration of dune due to high energy.
Massive Sandstone	S_m	Pinkish sandstone, medium grained.	Sedimentary structure obscured due to weathering effect. Continuous deposition of sand in high energy condition.
Laterite	C_l	Dark brown colored, sand size matrix, concretion dominating.	Period of non-deposition, hot and humid environment, (secondary).
			Alternating high and low energy condition. Suspended load deposits at low energy condition, sand deposits at

Shale with very fine Sand to Silt Streak and Lens	Sh_{ls}	Sandy to silty shale with sand lenses, lenses become thin and turns into streak.	intermittent high energy as ripple lenses. Mainly calm and quiet but intermittent high energy.
Sandstone Band	S_b	Massive sandstone, calcareous to siliceous band, sometimes ripple lamination present.	High energy sand deposition, cementing material diagenetic.
Mudstone Or Claystone	M_b	Massive clay, thickly bedded (found in Bhuban Formation).	Intermittent calm and quiet environment, suspended load deposits.
Lenticular Bedded Silty Shale	Sh_{ln}	Brownish gray in color with mud streak, containing mostly clay sized particles and clay minerals.	Calm and quiet environment with intermittent higher energy condition.
Wavy Bedded Sand-Clay Alteration	Sh_w	Ripple and lamination found in sand portion.	Alternating high and low energy condition. Suspended load deposits at low energy condition, sand deposits at higher energy.
Flaser Bedded Sandstone	S_f	Fine to very fine, flaser bedded sandstone.	High energy condition with intermittent lower flow regime.
Massive Claystone	M_m	Grayish colored, entirely composed of clay size particles.	Continuous suspended load deposition in calm and quiet environment.
Mudstone with Fine Sand-Silt discontinuous Streak and Lenses	M_l	Grayish colored, mostly composed of clay size particles with some discontinuous sand/silt streak or lenses.	Suspended load deposition in calm and quiet environment and intermittent higher energy condition.
Planar Cross Bedded Sandstone	S_p	Fine to medium grained yellowish sandstone with large scale planner cross bedding	
Sand Shale Alteration	F_l	Alteration of Sand size particle deposits and clay size particles deposits.	Alternating high and low energy condition. Suspended load deposits at low energy condition, sand deposits at higher energy.

3.1.1 Facies Association

Description of Facies Association

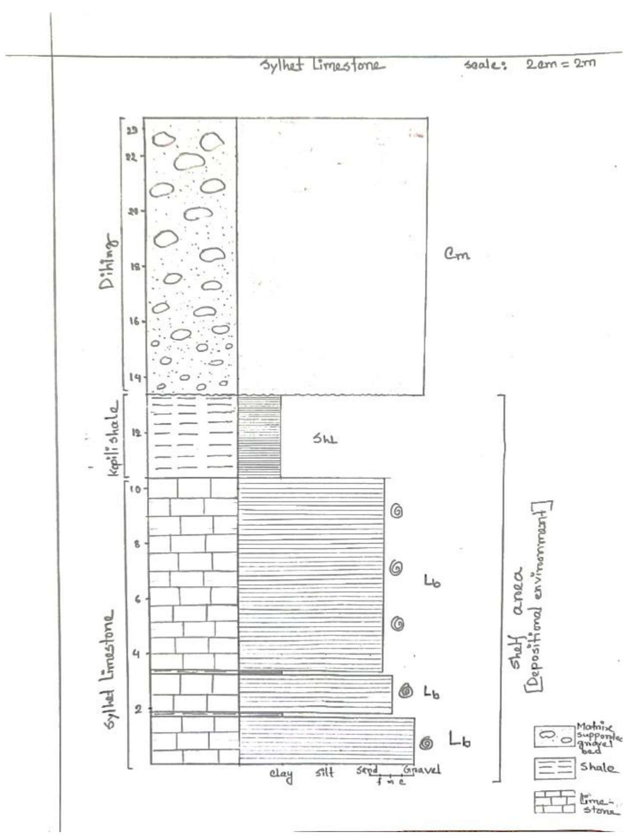
FA1: Carbonate platform

Forms in shallow marine environments composed primarily of carbonate sediment, such as limestone or dolomite. It is characterized by the accumulation of carbonate rocks and associated sediments, which are mainly composed of the remains of marine organisms like foraminifera.

Typically develop in warm and tropical settings with clear and relatively shallow water, as these conditions promote the growth of marine organisms that contribute to carbonate sediment production. The platform may extend over a large area and have a relatively flat or gently sloping topography.

Marine organisms extract dissolved carbonate ions from the water to build their skeletons or shells. Over time, as these organisms die, their remains accumulate and contribute to the growth of carbonate rocks. Sediments derived from the erosion of nearby landmasses, as well as the transport and deposition of fine-grained particles by waves and currents, may also contribute to the sediment accumulation on the platform. As the carbonate sediments accumulate, they undergo diagenesis, which involves processes like compaction and cementation. Cementation occurs when minerals, and forming solid rock.

Due to following characteristics, we can consider the Sylhet Limestone Formation of our investigated area is under Carbonate Plateform facies Association.



FA2: Shelf area

Shale is a type of sedimentary rock that is primarily composed of clay minerals and other fine-grained particles. The depositional environment of shale can vary, but it is commonly associated with quiet or low-energy environments such as lakes, lagoons, floodplains, and deep marine basins. The specific conditions and processes involved in shale formation can result in different types of shale deposits.

Shale can be associated with deltaic environments where rivers deposit large amounts of sediment at their mouths. As the river enters a body of water, such as a sea or lake, the sediment load decreases, and fine particles settle out to form layers of shale in areas of reduced energy.

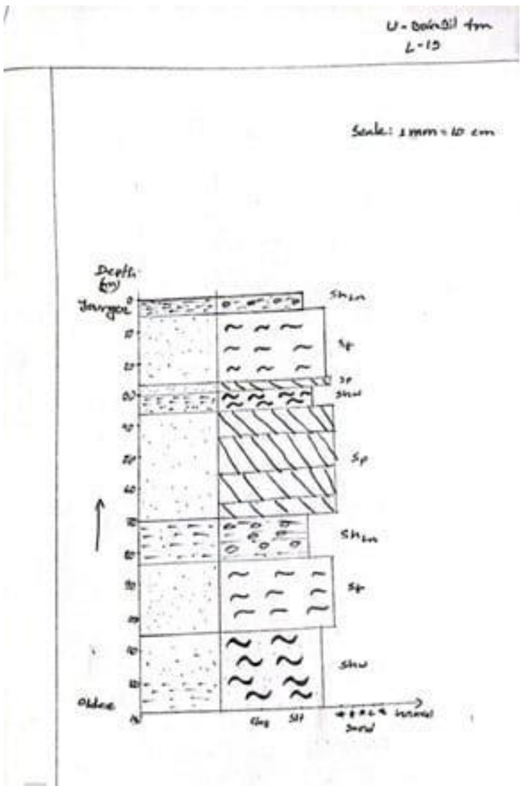
We found this type of deposits in many section mainly in kopili shale.

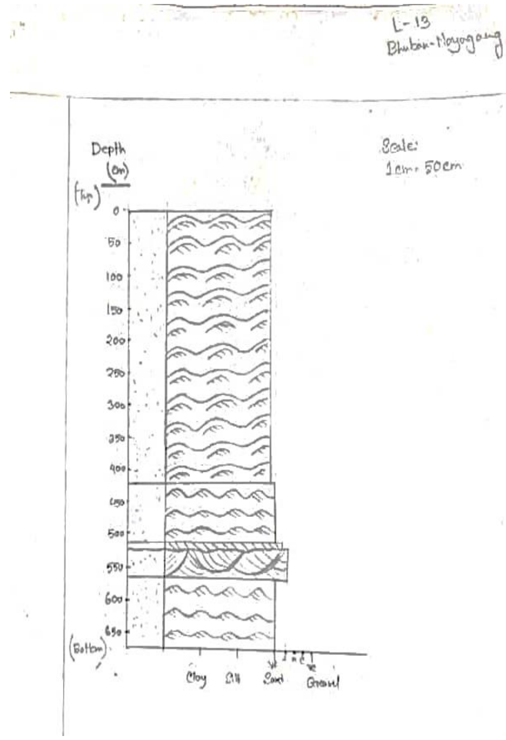
FA3: Tidal flat or tidal delta environment

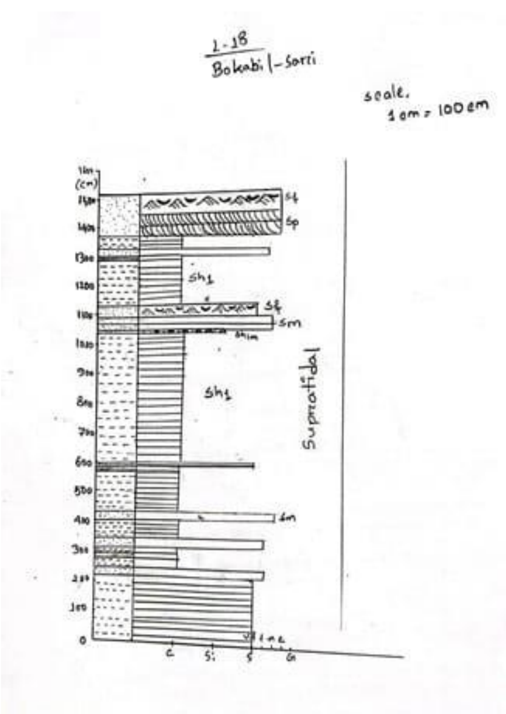
Deltaic processes were involved in the deposition of the Bhuban Formation. The sediments carried by rivers were sometimes discharged into the sea or large lakes, forming deltaic deposits. The deposition and subsequent alteration of sand shale can involve various geological processes.

Sand shale is typically formed in environments where a mix of sand and clay-rich sediment is deposited. This can occur in a variety of settings, such as river deltas, shallow marine environments, or offshore sedimentary basins. Sedimentation processes, such as river currents, ocean waves, or wind, transport the sand and clay particles and deposit them together. After deposition, the sand shale undergoes diagenesis, which refers to the physical and chemical changes that occur as sediment is transformed into rock. Diagenesis can involve compaction, cementation, and the alteration of mineralogy. The clay minerals in the shale component may undergo changes due to pressure, temperature, and the presence of fluids, leading to the formation of new minerals or the recrystallization of existing minerals. As the sand shale lithifies, minerals can precipitate from pore fluids and fill the spaces between the grains. Over time, the sand shale can be buried under additional layers of sediment. The increased pressure and temperature associated with burial can further compact the rock and promote cementation, leading to its lithification. Tectonic forces, such as compression or uplift, can affect sand shale deposits.

Bhuban and Bokabil Formation are found in this faccies Association


U-Bokabil fm
Scale: 1 mm = 10 cm
Depth (cm)
Younger
Older
Sp
Sp
Clay
Silt


L-13
Bhuban-Noyogaong
Depth (cm)
Scale: 1cm = 50cm
(Top)
0
50
100
150
200
250
300
350
400
450
500
550
600
650
(Bottom)
Clay
Silt
Sand
Gravel


L-18
Bokabil-Sorri
scale. 1cm = 100cm
St
Sp
Sh1
St
Sm
Sh1
Supratidal
0
100
C
Si
S
G

Some portions of the Bhuban Formation may exhibit characteristics of tidal flat environments.

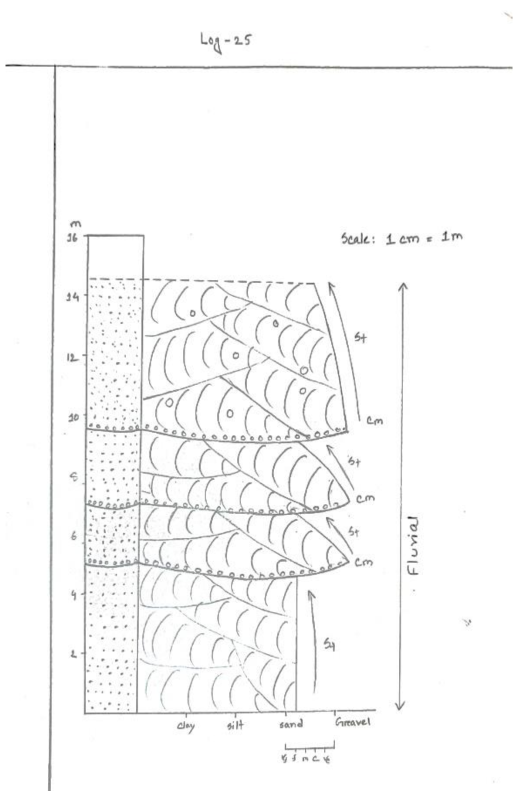
These tidal flat deposits within the Bhuban Formation would likely be represented by fine-grained sediments, possibly including mudstone or shale, and might show features such as ripple marks, mud cracks, or bioturbation.

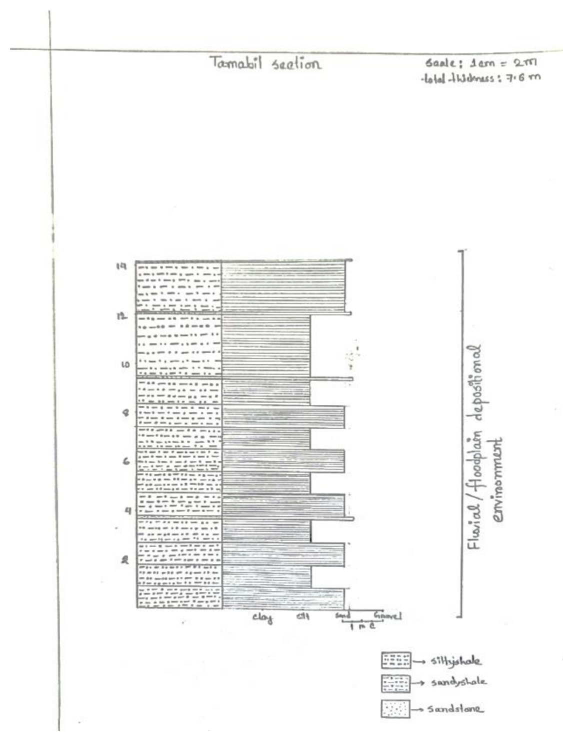
FA4: Fluvial environment

Rivers are significant agents of sediment transport. They carry sediment, including sand, from their source areas and deposit it along their channels and floodplains. Fluvial sandstone is commonly formed in riverbeds and adjacent areas where the energy of the water is sufficient to transport and deposit sand.

Ferruginous sandstone is a type of sandstone that contains a significant amount of iron oxide minerals, particularly hematite or goethite, which give it a reddish-brown color.

Sandstone can be deposited in fluvial environments, where rivers transport and deposit sediment. High-energy river systems can carry coarse sand and gravel, which can become cemented by iron oxide minerals, forming ferruginous sandstone. Tipam and Barail Formation are found in this facies Association.





The Tipam Sandstone was primarily deposited by river systems that transported sediment from the nearby source areas. These rivers transported sand and other coarse-grained sediments and deposited them in fluvial channels and floodplains environments.

Fluvial channels and floodplains also played a role in the deposition of the Barail Formation. The river systems that fed the delta transported sand and other coarse-grained sediments, which were deposited in the fluvial channels. The floodplains adjacent to the channels received finer-grained sediment, including silt and shale.

3.2 Grain Size Analysis

Sediment grain size analysis is used to determine the size distribution of sediment particles within a sediment sample. It provides valuable information about the sedimentary characteristics, depositional processes, and environmental conditions under which the sediment was deposited.

Grain size analysis involves measuring and classifying sediment particles based on their size. Sediment particles are typically categorized into different size fractions or classes, ranging from larger grains (gravel) to smaller grains (clay). The grain size analysis process involves the following steps:

1. Sample Collection
2. Sample Preparation
3. Sieving
4. Weighing
5. Calculation
6. Plotting

The examination of sedimentary rocks' grain sizes is done using a variety of techniques, including sieving, microscopic inspection, and settling velocity. The degree of sediment consolidation, nature of the inquiry, and other criteria may restrict the use of a certain procedure. To determine the grain size, we utilize the sieve method. It serves as the industry standard for laboratory analysis.

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:

- Techniques for measuring grain size and expressing it in terms of some type of grain size of grade scale.
- Presenting them in graphical or statistical form so they can be easily analyzed.
- 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-

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.
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 2-M values

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

(I) **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 3-D values

Values from	To	Equal
□□□□	□□□□ □	**very well sorted**
□□□□	□□□□ □	**well sorted**
□□□□	□□□□ □	**Moderately well sorted**
□□□□	□□□□□	**Moderately sorted**
□□□□	□□□□ □	**poorly sorted**
□□□□	□□□□ □	**very poorly sorted**
□□□□	□	**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 □ values. Populations with a tail of excess coarse particles are negatively skewed or coarse skewed. It means skewed towards negative □ 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 4-S Values

Values from	To	Mathematically	Graphically Skewed to the

+1.00	+0.30	Strongly positive skewed	**Very Negative phi values, coarse**
+0.30	+0.10	Positive skewed	**Negative phi values**
+0.10	-0.10	Near symmetrical	**Symmetrical**
- 0.10	-0.30	Negative skewed	**Positive phi values**
- 0.30	**-1.00**	**Strongly negative skewed**	**Very Positive phi values, fine**

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 5-K Values

Values from	**To**	**Mathematically**	**Graphically Skewed to the**
+1.00	+0.30	Strongly positive skewed	**Very Negative phi values, coarse**
+0.30	+0.10	Positive skewed	**Negative phi values**
+0.10	-0.10	Near symmetrical	**Symmetrical**
- 0.10	-0.30	Negative skewed	**Positive phi values**
- 0.30	**-1.00**	**Strongly negative skewed**	**Very Positive phi values, fine**

Table-11: Result and discussion of grain size analysis

Sample No	Graphic Mean (M)		Graphic Standard Deviation (Sorting) D		Graphic Skewness (S)		Graphic Kurtosis (K)	
	Value	Interpretation	Value	Interpretation	Value	Interpretation	Value	Interpretation
Location-18	2.043	Fine sand	1.355	Poorly sorted	-0.413	Strongly negative skewed	1.925	**Very Leptokurtic**
Location-20	2.17	Fine sand	1.52	Poorly sorted	0.49	Strongly positive skewed	1.06	**Mesokurtic**
Location-21	2.52	Fine sand	1.10	poorly sorted	0.26	Positive skewed	1.77	**Very Leptokurtic**
Location-25	2.34	Fine sand	1.51	poorly sorted	0.23	Positive skewed	1.12	**Leptokurtic**
Location-28	1.95	Medium sand	1.33	poorly sorted	0.06	Near symmetrical	0.90	**Mesokurtic**
Location-30	**3.05**	**Very Fine sand**	**1.35**	**poorly sorted**	**-0.05**	**Near symmetrical**	**2.05**	**Very Leptokurtic**

Figure 1 Cumulative curve of different samples

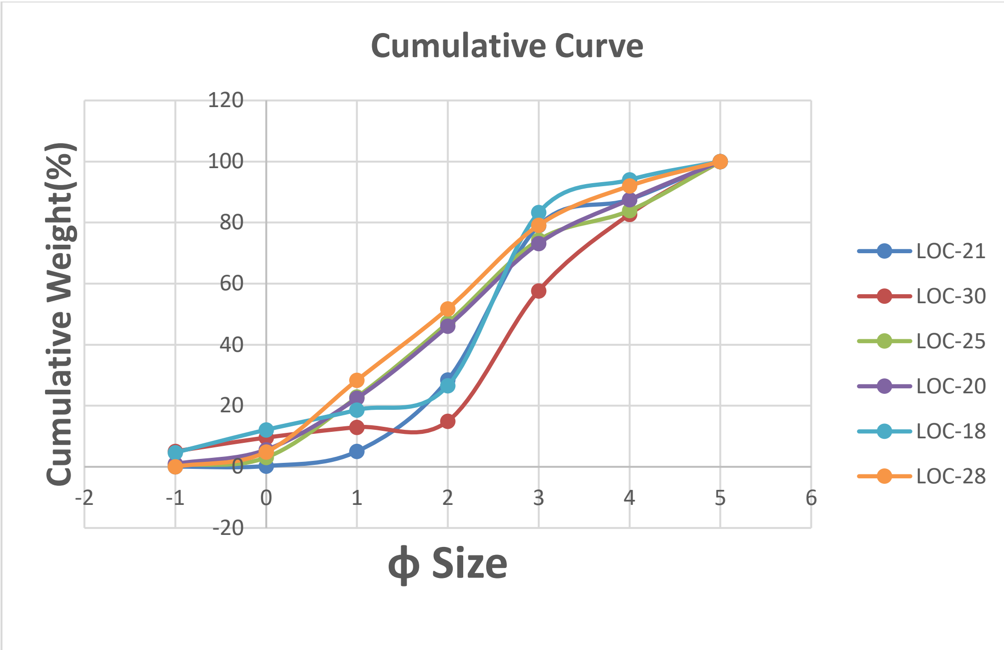
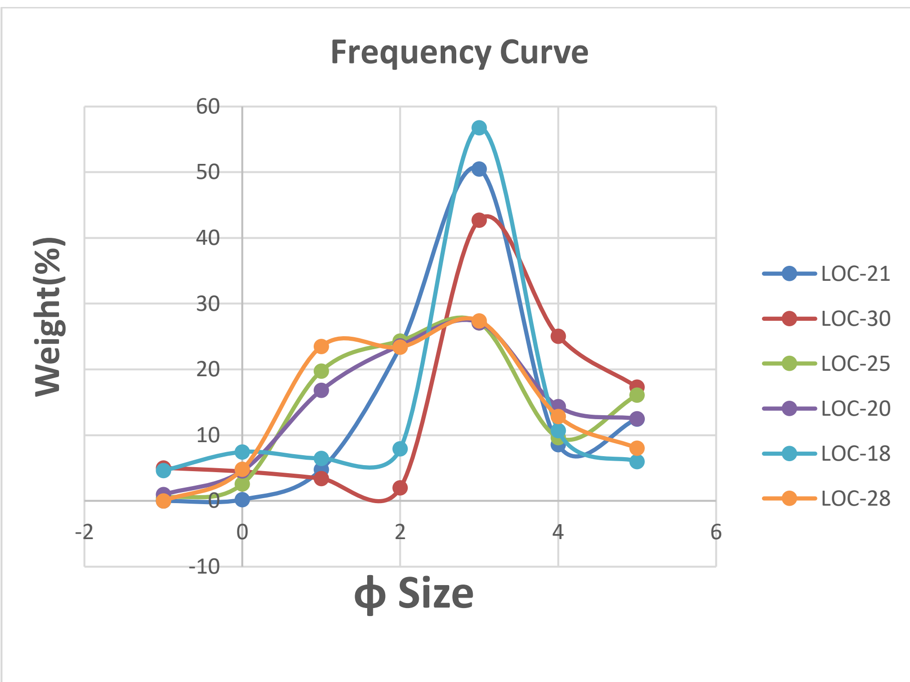


Figure 2 Frequency curve of different samples



3.2.1 Interpretation of Depositional Process

3.3 Petrography

Petrography involves the detailed study and description of rocks and their mineralogical, textural, and structural characteristics. It focuses on the microscopic examination of rock samples to understand their composition, mineral assemblages, textures, and the processes that formed them. Petrography is used to unravel a particular area's geological history and conditions.

Critical aspects of petrography include:

1. Mineral Identification
2. Rock Texture and Structure
3. Rock Classification
4. Petrologic Analysis

In optical mineralogy and petrography, a thin section (or petrographic thin section) is a thin slice of a rock or mineral sample, prepared in a laboratory, for use with a polarizing petrographic microscope, electron microscope and electron microprobe. Petrographic analysis describes the texture (grain size, sorting, and grain contacts), sedimentary structures (laminations, bioturbation), framework grain composition, authigenic minerals, and types and distribution of macro porosity seen in a thin section. A thin sliver of rock is cut from the sample with a diamond saw and ground optically flat. It is then mounted on a glass slide and ground smooth using progressively finer abrasive grit until the sample is only 30 μm thick.

The method uses the Michel-Lévy interference color chart to determine thickness, typically using quartz as the thickness gauge because it is one of the most abundant minerals. When placed between two polarizing filters set at right angles to each other, the optical properties of the minerals in the thin section alter the color and intensity of the light as seen by the viewer. Different minerals have different optical properties so that most rock-forming minerals can be easily identified. Thin sections are prepared to investigate the optical properties of the minerals in the rock. This work is a part of petrology and helps to reveal the origin and evolution of the parent rock.

From the studied area, we made three thin sections from six rock units. These are:

3.3.1 Heavy Mineral Analysis

Heavy Mineral

A. Zircon

<u>Observation under plane polarized light(10X)</u>

Colorless mineral which is prismatic in form with high relief where cleavage is absent and no pleochroism.

<u>Observation under cross polarized light(10X)</u>

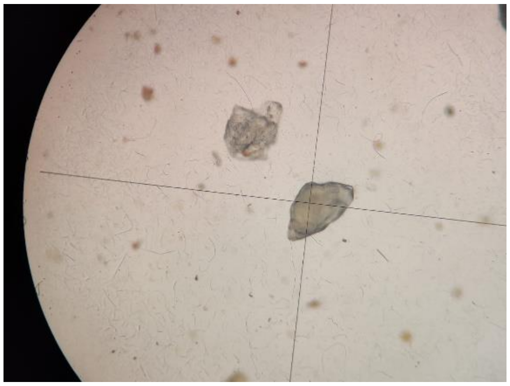
Parallel extinction with very strong birefringence

<u>Other properties:</u>

Inclusion is present as small dark spot with the presence of zoning along crystal boundary where twinning is absent in the mineral.

Nomenclature:

From the above microscopic observation particularly from it’s diagnostic properties,it’s assumed that the observed mineral grain in the supplied slide is Zircon whih is a mineral of Tetragonal system,silicates class,neo-silicate sub-class and Garnet group.



Cross

Plane

B. Garnet

Observation under plane polarized light(10X)

Pale brown mineral which is euhedral in form with very high relief where cleavage is absent and no pleochroism.

Observation under cross polarized light(10X)

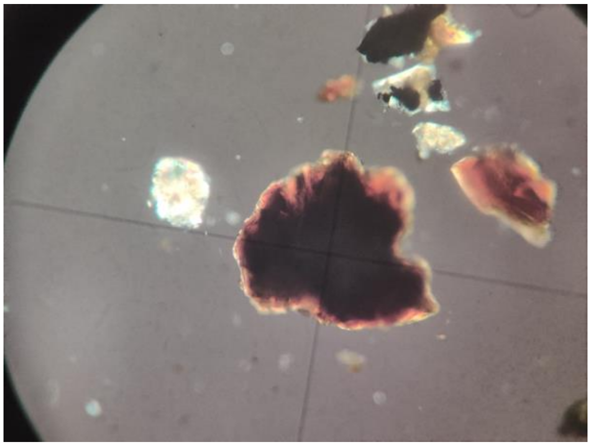
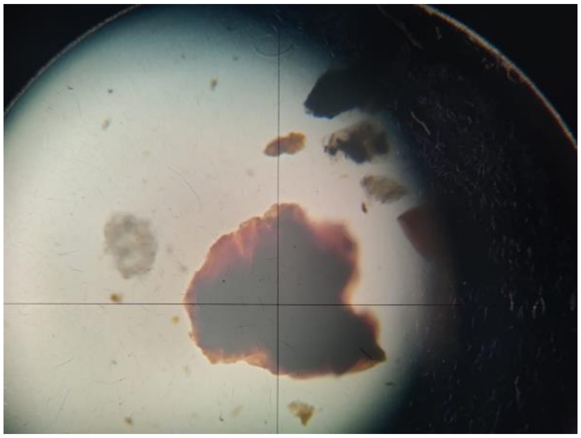
no extinction and no birefringence

Other properties:

Absent of inclusion,twinning and zoning

Nomenclature:

From the above microscopic observation particularly from it’s diagnostic properties,it’s assumed that the observed mineral grain in the supplied slide is Garnetwhih is a mineral of silicates class,neo-silicate sub-class and Garnet group.

Plane Cross

C. Kyanite

Observation under plane polarized light(10X)

Colorless to pale blue mineral which is elongated tabular in form with high relief where one directional cleavage is present with no pleochroism.

Observation under cross polarized light(10X)

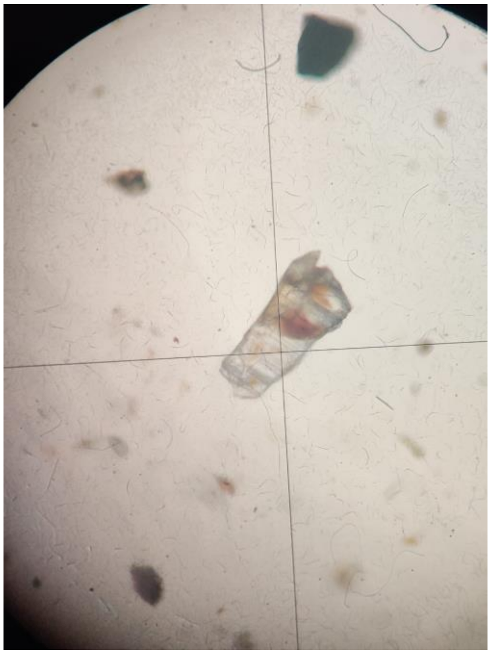
oblique extinction with moderate birefringence

Other properties:

Absent of inclusion,twinning and zoning

Nomenclature:

From the above microscopic observation particularly from it's diagnostic properties,it's assumed that the observed mineral grain in the supplied slide is kyanite whih is a mineral of triclinic system,silicates class,neo-silicate sub-class and Aluminosilicate mineral group.

plane cross

D. Staurolite

<u>Observation under plane polarized light(10X)</u>

Colorless to pale brown mineral which is prismatic in form with moderate relief where one directional cleavage is present with no pleochroism.

<u>Observation under cross polarized light(10X)</u>

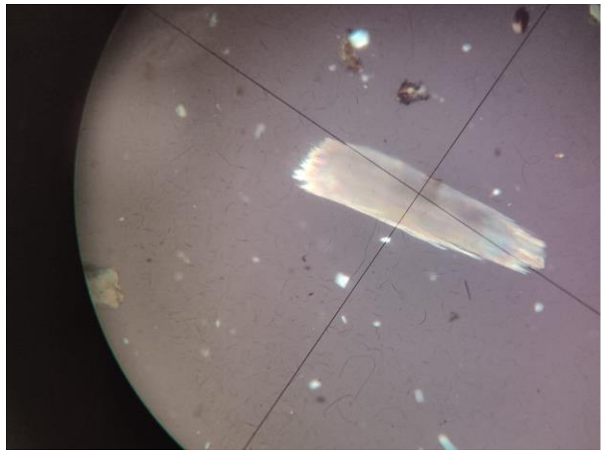
parallel extinction with moderate birefringence

<u>Other properties:</u>

Absent of inclusion,twinning and zoning

<u>Nomenclature:</u>

From the above microscopic observation particularly from it's diagnostic properties,it's assumed that the observed mineral grain in the supplied slide is sillimanite which is a mineral of orthorhombic system, silicates class,neo-silicate sub-class and Aluminosilicate mineral group.

plane Cross

3.4 Provenance Analysis

Provenance primarily focuses on determining the source of the rock material that was deposited in a particular area. By studying the source area, valuable information about the characteristics of the rock can be inferred. Previous investigations of the area have revealed that the rock constituents consist of muscovite, biotite, and quartz. Feldspar also exhibits noticeable normality. The angularity of the minerals suggests a probable origin from metamorphic and igneous sources.

The metamorphic and igneous rocks that could have supplied the detrital constituents are known to occur in the Assam plateau, Shan plateau of Burma, and the igneous and metamorphic complex of India. The remarkable angularity of quartz grains and the presence of feldspar indicate that they likely come from nearby sources. Their angular to subangular shape suggests a possible derivation from the distant north and northwestern Shillong plateau.

Chapter Four

Structure and Tectonics

i. Bedding geometry

The main objective of this study is to recognize the geometrical element of the folded structures for the classification of fold and to evaluate the tectonic deformation intensity. using the stereographic projection technique which is carried out by stereonet10.

Following steps has been taken for structural interpretation in stereographic analysis:

- Drawing great circle and pole point distribution: The calculated attitude data added to the equal area stereogram which will give the great circle (β diagram) and will show the pole point distribution (π diagram).
- Density contour of the pole point distribution: Displaying the density of data of the structure.
- Rose diagram: This diagram is plotted based on strike orientation.
- Determining geometrical elements: Data of the beds are sorted out and then analyzed to calculate the pole value (azimuth & dip) based on mean vector and contour center.

the following three basic geometrical elements of fold classification have been calculated:

1. Trend & plunge fold axis
2. Interlimb angle and
3. Strike & dip of axial plane

Strike orientation in five investigated sections

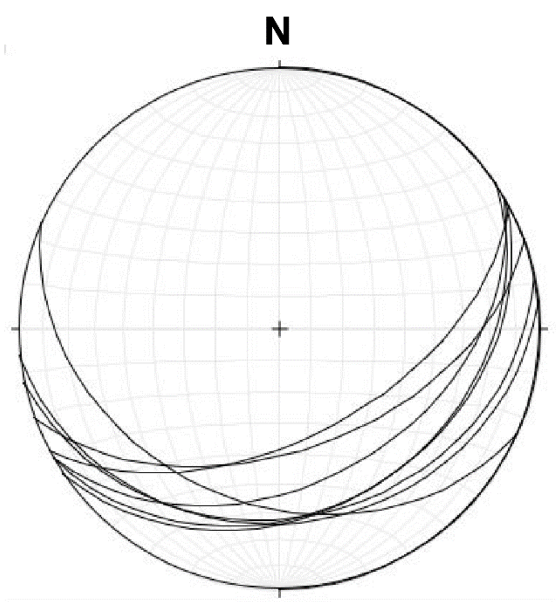


Figure: Planes of the Dauki River section

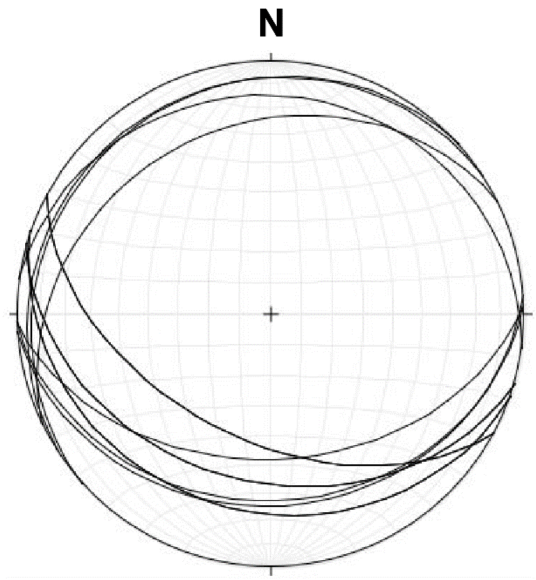


Figure: Planes of the Jaintiapur-Tamabil roadcut section

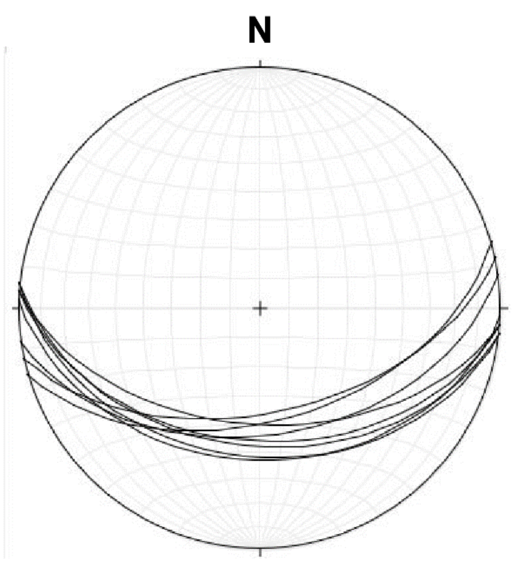


Figure: Planes of the Nayagang section

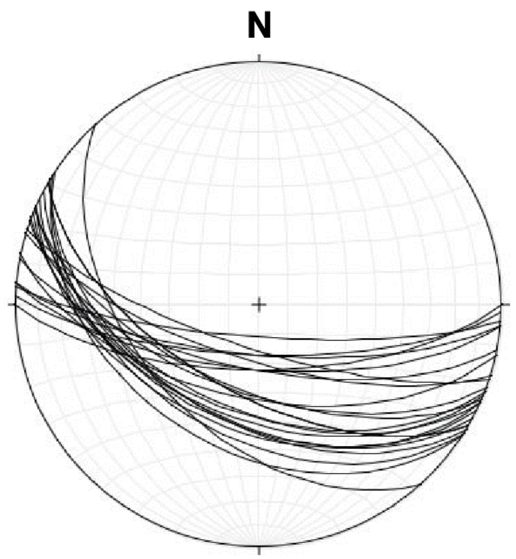


Figure: Planes of the Sari River section

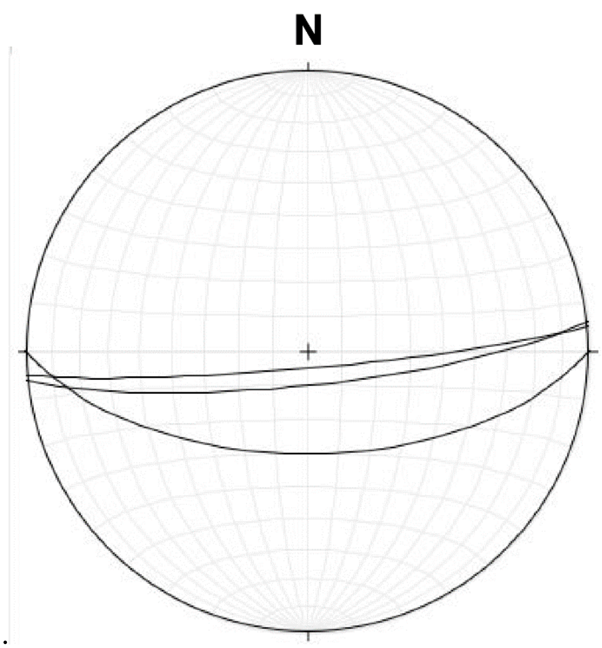


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Figure: Planes of the Dupigaon section

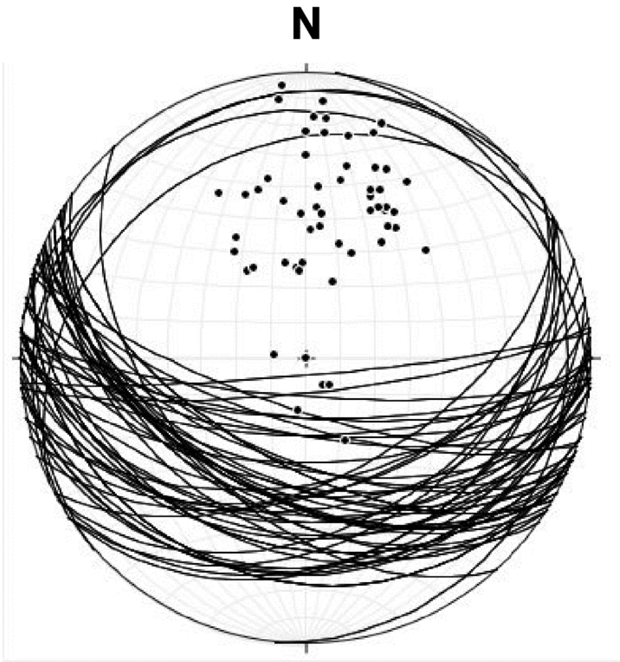


Figure: Planes and poles of the whole investigated area

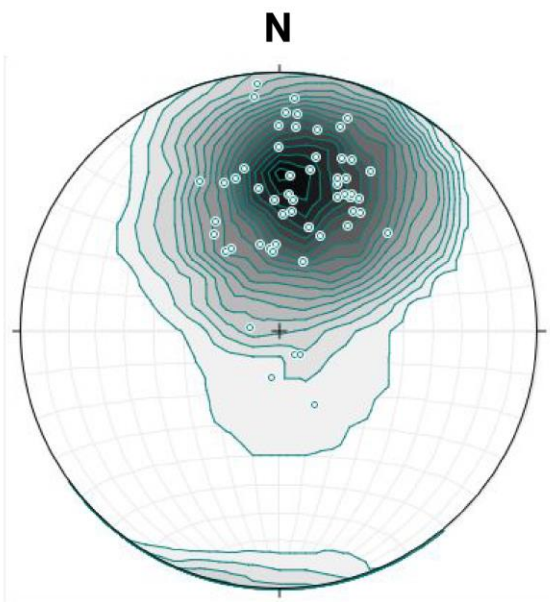


Figure: Contour diagram of the poles to the bedding planes of the investigated area.

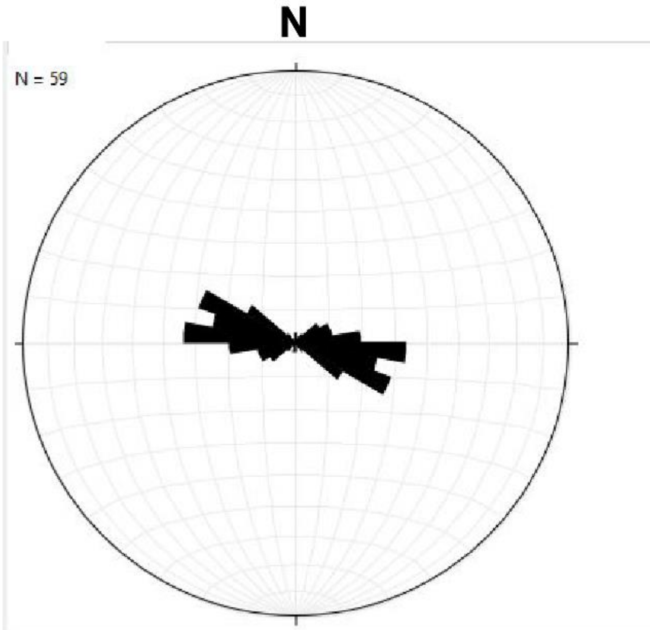


Figure: Rose diagram based on bedding strike orientation.

Result and Discussion:

Geometric elements analysis is done mainly based on the bedding planes attitude. In total, approximately 59 measurements of bedding planes were taken during field study. The pole of the bedding planes as well as the great circle have been plotted on the Schmidt's equal area lower hemisphere projection and represent as Beta - Pi diagram (Billings, 1974; Rowland et al., 2007; Lisle et al., 2004). A color contoured diagram has been constructed and superimposed on top of the Pi-diagram. The contour diagram is constructed with Kamb contour (Kamb, 1959), where the contour interval is 1 sigma,

From the Beta–Pi diagram all bed encompasses the southern part of the stereonet and the remaining northern part is completely blank. The dip directions of all beds are almost toward due S or S-w.

From the Rose diagram based on bedding strike orientation where strike directions are plotted as 5° class interval and strike is oriented almost E-W direction.

From the above analysis especially based on single dip directional and the distribution of poles, it can be concluded that Jaintiapur and adjoining area comprises a broad homoclinal fold more than monoclinal or due to almost same dipping it is a Homoclinal Fold, where the beds are dipping almost toward Due South or S-W.

ii. Deformation

Dauki Fault: The overturning nature of beds in the fault zone may demonstrate the possibility of reverse or thrust type of fault. The flow direction of the Dauki River is another indicator to the presence of a major fault

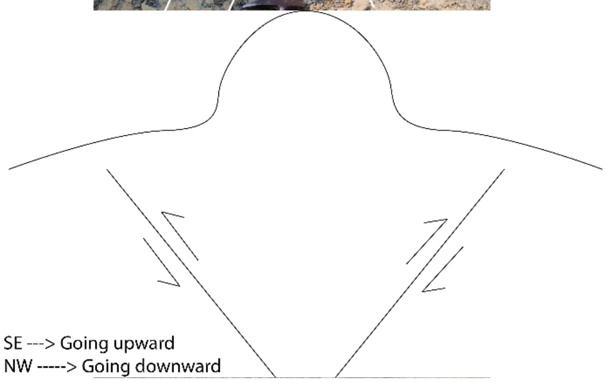
Figure: Large fault Escarpment at Dauki river section

Joint set: Joints may be defined as divisional planes or surfaces that divides rocks and along which there has been no visible movement parallel to the plane or surface. The joints can be found in Jaintiapur and adjoining area as minor structure. This is more common in Dauki river section and in Jaintiapur-Tamabil road cut section. In Jaintiapur-Tamabil road cut section section it has been observed oblique joint, diagonal joints and joint sets. In Dauki river section few closely spaced joints of variable orientation are noticed in Sylhet Limestone.

Figure: Joint set at Jaintiapur-Tamabil road cut section

Thrust-induced drag folds: The thrusts are produced presumably by the sub-horizontal compression at the northern edge linked to the DFZ. In general, to the north and close to the DFZ, the thrust dips at a much higher angle, which gradually decreases towards south, and finally become sub-horizontal. A decrease in the degree of deformation in the direction of transport (owing to the formation of frontal thrust with low angle towards up-dip) and presence of the rigid Shillong Plateau as the hanging wall block are responsible for such a gradual variation of dip. The local thrust slices with similar vergence of the DFZ also occur here.

Figure: Thrust-induced drag folds



Pop-up structure: refers to a type of geological structure that occurs when a relatively shallow section of crust is pushed upward along a fault line, resulting in the exposure of deeper rock layers. This upward displacement can create a sudden change in elevation, forming a localized topographic feature.

Figure: Sketch of Pop-up structure

Small-scale joints: In the Sylhet area of Bangladesh reveal fractures or cracks in rocks that provide insights into the region's geological history. These narrow fissures, ranging from millimeters to centimeters in width, are a result of tectonic forces and reflect the ongoing tectonic activity in the seismically active zone.

Figure: Small-scale joints in Tamabil Section

Shearing: During shearing, rocks can experience different types of movement. They can slide past each other horizontally, creating a strike-slip fault where the displacement is mainly horizontal. Alternatively, rocks can move vertically along a fault plane, resulting in dip-slip faults such as normal faults (caused by extensional forces) or reverse faults (caused by compressional forces). The Sari River section in the Sylhet area provides evidence of the shearing effect, which has occurred due to the transpressional force exerted between the Indian and Burmese tectonic plates.

Figure: Shearing effect at Sari River section.

iii. Structural and tectonic interpretation

The Sylhet region exhibits a diverse range of geological structures and is influenced by complex tectonic processes. This area is situated within the broader context of the Bengal Basin, which is characterized by its sedimentary cover and active tectonics.

The primary geological structure in the Sylhet region is the Surma Basin, which is a part of the larger Bengal Basin. It is a sedimentary basin formed by the deposition of sediments eroded from the Himalayas and transported by rivers. The Surma Basin consists of various rock formations, including sandstones, siltstones, shales, and conglomerates.

Tectonically, the Sylhet region lies within the convergence zone between the Indian, Burmese and Eurasian plates. The Indian plate is moving northward and colliding with the Eurasian plate, resulting in ongoing tectonic activity. The tectonic processes in the region include compression, thrusting, and folding, which have led to the formation of mountain ranges, such as the Meghalaya Plateau and the Khasi and Jaintia Hills to the north of Sylhet.

The Sylhet region also experiences seismic activity due to the tectonic forces. Earthquakes are relatively common, and the region is part of the broader seismically active zone known as the Shillong Plateau. The tectonic activity and seismicity contribute to the development of faults, fractures, and joints, which play a role in the geological evolution of the area.

CHAPTER FIVE

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.

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 of the Assam region.

5.1 Stratigraphic Unit

Based on our field observations, nine litho-stratigraphic units were found. These units from Oldest to Youngest are Unit-A (Limestone), Unit-B (Shale), Unit-C (Pinkish Sandstone), Unit-D (Sandy to Silty Shale), Unit-E (Alternation of Sandstone and Shale), Unit-F (Ferruginous Sandstone), Unit-G (Mottled Clay), Unit-H (Variegated Colored Sandstone) and Unit-I (Matrix Supported Gravel Bed). 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.

Table: Stratigraphic table of the investigated area.

Relative Age	Rock Unit	Formation	Lithology	Depositional Environment
Youngest to Oldest	Unit-I	Matrix Supported Gravel Bed	Yellow and grey, medium grained, occasionally pebbly sandstone	
	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	Fluvial

			moderate to poorly-sorted.	
	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.	Fluvial (Overbank)
	Unit-F	Ferruginous 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.	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	Deltaic

			medium grained with moderate compactness. Parallel lamination with interbedded shale, wavy, flaser and lenticular bedding, also nodular, flame, and hummocky structures were also found.	
	Unit-D	Sandy to 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 were also found.	Shallow Marine
	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	Deltaic to Fluvial

			cross lamination, trough cross bedding, presence of carbonaceous matter, iron incrustation, and burrows	
	Unit-B	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.	Shallow Marine
	Unit-A	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.	Shallow Marine

5.2 Correlation

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.

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

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-I	Matrix Supported Gravel Bed	Yellow and grey, medium grained, occasionally pebbly sandstone	Dihing	Dihing	Pebbly Sandstone, clayey sandstone with interbed of mottled clay		Pleistocene
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	Tipam	Girujan Clay	Mottled Clay	Fluvial (Overbank)	Late to Early Pliocene

		high plasticity with high content of organic matter, massive sedimentary structure.					
Unit-F	Ferruginous 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	Surma	Bokabil	Sandy Shale	Deltaic	Late Miocene

		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.					
Unit-D	Sandy to 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 were also found. In addition, calcareous		Bhuban	Silty Shale	Shallow Marine	Middle to Early miocene

		sandstone band was also observed.					
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	Shale	Dark black in color with abundant clay sized particles. This rock unit contains argillaceous cementing materials and is fissile in nature. Presence of	Jaintia	Kopili Shale	Greyish Black Shale	Shallow Marine	Middle to Early Eocene

		Pelecypod was found.					
Unit-A	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	

CHAPTER SIX

Economic Deposit

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 (Sandy to 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 nine unit namely Unit-I (Matrix Supported Gravel Bed) is correlated with Dihing Formation, 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 (Ferruginous Sandstone) 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-D (Sandy to 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 (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 (Shale) might acts as a source rock, while Unit-D (Sandy to 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 et

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