2.1 INTRODUCTION

It is only after a detailed study that one makes conclusions / inferences on the depositional environment of lithoassociations, their provenance, palaeoflow or brittle effects etc etc. These conclusions are restricted to geographical parameters within which the geological setting is studied. Henceforth, field study, sampling etc are of immense significance as they govern the post-analytical endeavours. The present attempt seeks to reflect the field settings as humanely as possible.

The study area constitutes approximately 25 sq. kms. (Toposheet no. 83C/8). Spread out at a distance of one and half hours from Silchar towards north-west wards along National Highway no. 44, the present study area is a part of the greater Barail Range of hills and as such it exhibits a very undulating topography. Towards east and north along the National Highway, the thickly vegetated Barail ranges sprawls and, towards west and south-west the hill ranges culminates gradationally against the huge alluvial plains of Bangladesh. The subsinous Lubha river which is the main drainage conduit of the area flows along the National Highway no. 44. in this area in a wavy and cross-cutting manner. The river valley which exudes a gorge like look at places show the extent / height of the exposures which can be traced right from the hill top to the river bank covering a height of roughly 100 mts. Climatic conditions aided by physical setup of the lithounits have reduced the area into a denudated hilly tract in patches resulting in thick soil cover, rich vegetation, obliteration of the nature of outcrops - erosion of many vertical sections consequently hampering the normal process of sampling. All the samples were taken after digging atleast 1 ft. both in the available vertical sections and the surficial ones. Enclosed here are certain salient features of the in-field litho-settings.

2.2 FIELD SETTING

The present area of study falls in the early Tertiary geosynclinal margin running along the southern extension of the Shillong Plateau. The rock exposures are predominantly arenaceous with alternations of small to moderate shale bands and, occasional development of carbonaceous shale, (Plate no. 11) and coal streaks.

The sandstones show both massive, (Plate no. 3) and well laminated character, (Plate no. 5). The individual beds are 5-30 cm thick, comprising friable to massive, fine to medium
grained, grey to brownish grey coloured. Thin internal laminations, sinous and straight crested ripple marks, (Plate no. 10) are observed at places along with planar to trough cross stratifications. The general strike trends of the lithoassociations are NE-SW with moderate to high dips (30°-41°) towards SE. The sandstone layers show blocky as well as slabby bedded features and fining upward character towards the shaly contact. The sandstone - shale alternations towards the base grade upward into thick bedded sandstones with thin shaly inter-beds near the top. Overall, it is also seen that the coarseness of the sands increase in a north westerly direction. The argillaceous and carbonaceous content however increases south easterly. Overall, the fining upwards characteristics of the lithoassociations look to be seasonal increaments. It is also seen that the blocky bedded character of the arenaceous rocks prevail wherever the organic content is less or nil. In the vicinity of shales or carbonaceous shale, slabby laminated features dominate. Interlived shales or carbonaceous shales are zones along which weathering, soil forming processes dominate, (Plate no. 14). These fine units are mostly thin and show pinching and swelling character in patches hosting fine grained sandstones. Such zones show discrete sedimentary structures like cross-laminations, ripple marks and convolutions. Carbonaceous shales can be distinguished from the shaly bands by their darker colour and pyritiferous specks. Sporadic coaly specks with lower earthy lustre suggest coalification activity in patches, (Plate no. 12). Fossilic contents are very sparse or rare.

Two sets of joints are prominent in the area - one along the bedding planes and the other at 90° from it, (Plate no. 4). The blocky or slabby character of the beds, their steeper inclinations suggests effects of episodes of tectonic plays in the neighbouring area. Presence of the Dauki fault south of the area and, the presence of the Cachar-Tripura folded belt in the vicinity vindicates the same.

Broadly, the area from north to south (trespassing the study area) shows younging trend. Existing literatures and field reports indicate the presence of Sheila Formation north and along of the National Highway no. 44 with the characteristic sandstone-limestone alternations. South of the Sheila Formation exposures and upto the Sonapur Bridge are exposed the Kopili Formation. Kopili Formation consists of fine to moderate alternations of brown to grey splintery shales and fine to medium, grey to hay coloured friable to compact and massive sandstones. The sandstones are carbonaceous rich in patches. Apparently, the difference between the Kopili sandstones and the sandstone of the studied area cannot be marked out. They show a gradational variation. However, there is a distinct difference in the amount of finer shaly materials in these two areas. The Kopilis contain more shales. The shales of the Kopili Formation are brown to grey, sometimes iron stained, hard and splintery while, the Laisong shales are dark
grey, moderately hard, compact and occasionally silty. Moreover, the Kopilis show moderate to subhorizontal bedding compared to the steeper attitudes of the studied area. Such differences can be easily visualised across the Sonapur bridge. The characteristics of the lithounits of the study area which overlie the Kopilis to the north seem to tally with that of the Laisong Formation when compared with the pre-existing literatures, (cf., ONGCL, 1993; Ganguly, 1993). South of the mile-post 149, distinct increase in shale content is seen inter-layered with very fine grained sandstones. Further south towards Umkyang, there is more of shale than sandstones. The sandstones are fine to medium grained having ferrugeneous sandy matrix. They alternate with well laminated shales. These may be classed as Surmas (Bhuban Formation). Thus, one can see a younger trend from north to south, (Map 2) along the National Highway no. 44. Considering this trend and, an increase in the amount of shale one may visualise deepening of the basin southwards.

The generalised lithostratigraphic succession from north of Sonapur bridge to further south of milepost 149 is -

<table>
<thead>
<tr>
<th>AGE</th>
<th>GROUP</th>
<th>FORMATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recent</td>
<td></td>
<td>Soil / Alluvium</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Unconformity</td>
</tr>
<tr>
<td>Miocene</td>
<td>Surma</td>
<td>Bhuban</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Unconformity</td>
</tr>
<tr>
<td>Oligocene</td>
<td>Barail</td>
<td>Laisong</td>
</tr>
<tr>
<td>Eocene</td>
<td>Jaintia</td>
<td>Kopili</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(south)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(north)</td>
</tr>
</tbody>
</table>

2.3 LITHOFACIES

A sedimentary rock is not only a product of a specific provenance transport history but it is also a product of the environment of deposition. The sole task is to decode these imprints from the clasts. There have been many ways devised for reading and understanding the 'clasts' history and, lithofacies analyses is one of them (Allen, 1970; Miall, 1978; Reinick and Singh, 1980) is one amongst them. A sedimentary facies is a mass of sedimentary rock which can be defined and distinguished from others by its geometry, lithology, sedimentary structures, palaeoecurrents patterns, fossils etc. A sedimentary facies is the product of a depositional environment. The key to the interpretation of facies is to combine observations made on the spatial relations and internal characteristics - lithology and sedimentary structures, (Middleton, 1978a). A genetical explanation for an ancient phenomenon is always made by an analogy with that of the modern happenings.
2.3.1 METHODS OF STUDY

At each exposure, individual lithounits were identified based on gross lithology, sediment texture (grain size) and, sedimentary structures in detail. On the basis of observational physical characteristics, each bed was given a facies name and a symbol following the lithofacies code scheme of Miall (1978) with inputs also from Walker (1984).

The overall generalised litholog (Fig. 2.1) of the area has been constructed after detailed investigation and correlation of a number of vertical sections dispersed in the area of investigation.

2.3.2 LITHOFAUCIES DESCRIPTION

Considering the genetical implications, even the smaller discernible lithounit characteristics are enlisted below -

I. Massive Sandy facies (Sm)

The lithofacies consists of sand without any distinct bedded features or stratification. Composed of fine grained sands, these are seen as thicker units (thickness seen upto 20 metres) and also as small lenses within the shaly layers.

These may be interpreted as a product of sediment transportation in planar sheets under very high energy conditions or deposited as seasonal loads (Casshyap and Kumar, 1987; Fielding, 1988).

II. Horizontal stratified sandy facies (Sh)

The horizontal stratified sandy facies is developed both in the lower and upper parts of the exposed litho-logs. Laminations are continuous and distinct due to colour variation and presence of mica. At places, the laminations show some irregular undulations due to parri-passu sediment deformation. Number of dark lamina are less than that of the light laminae. Beds of this facies are usually continuous across the width of the outcrop and they commonly overlie and underlie the facies Sp and St. They show the maximum thickness of 28 metres which is highest amongst all the other lithofacies units of the present area.

Horizontal stratified facies can develop under two contrasting conditions - in shallow water and during the flood stage (Miall, 1978). Horizontal stratified units with fine sands in the lower part of the bed may be interpreted as sands transported in planar sheets under high energy conditions (Casshyap and Kumar, 1987), usually $F>1$, (Potter et al., 1988).
III. **Planar cross stratified sandy facies (Sp)**

Planar cross strata occur in small scales, (Plate no. 9). They are commonly associated with trough cross stratification and horizontal stratification. The top and bottom contact are sharp and, these cross sets occur as single sets or cosets. The sets are usually laterally extensive. Thickness of the whole sets are on an average 25 to 30 cms whereas, the whole lithofacies unit extend on thickness upto 8 metres. Certain sets of facies Sp develop on a flat surface that truncate facies St. This unit may be thought of as a product of lower flow regime of sedimentation probably associated with ripple migration.

IV. **Trough cross stratified sandy facies (St)**

Facies St is composed of apparently massive to poorly defined cross bedded sandstones with depth of trough ranging upto a maximum of 3.5 cms. Trough cross stratification occur as cosets with the trough being regularly stacked. Composed of moderately to poorly sorted medium to fine grained sands, the cross strata are truncated to the top set and are at an angle with the bottomset, (Plate no. 7). In certain patches, the top portion looks erosional. The stratification is poorly defined in many cases due to poor sorting as well as lack of fine material needed to show up the cross strata. Scattered granules and pebbles, (Plate no. 8) occur at the base of some troughs. They show a maximum thickness of 3 metres.

The trough cross strata is mainly the result of scouring of channels due to sediment laden flood water that filled them as flood power decreased (Fielding, 1988). The small scale trough cross stratification may be the result of infilling of circular or elliptical shaped scours connected with migration of tongue shaped lingoid current ripples. Overall, they are a product of lower flow regime.

V. **Ripple laminated sandstone (Sr)**

This lithofacies is sporadically well represented atop the facies types of Sp and St. Facies Sr consists of both planar and cross laminated beds. Rarely climbing ripple lamination is attached with facies Sr and wherever they are, these beds show Type-I (both lee and stoss sides being well preserved). and Type-II (Only lee side is preserved) characteristics (Reinick and Singh, 1980). Transition from one type to the other cannot be worked out. Certain patches show convolutions too. Thickness of this unit which depicts a low flow regime is upto a maximum of about 3 metres.

VI. **Parallel laminated fine sand, silt and clay facies (Fl)**

In the parallel laminated facies each lamina is parallel to the lower set of boundary. The
laminations show variation in colour and are comprised of fine sand, silt and clay.

The lamination in silt and clay are developed under suspension, in waning stages of flood (Miall, 1985). This facies was developed when the flow energy was sufficient to distribute the finer sediments.

VII.  **Carbonaceous shale, Coal facies (C)**

This facies type is very rare in exposure. It is a composite of high organic matter plus mud films. A product of swampy like environment, the coaly parts are of low grade nature - mostly peat type.

VIII.  **Massive to poorly laminated shale / Mudstone (Fm)**

This facies consists of apparently massive to poorly laminated shale and mudstone, (Plate no. 6). Commonly alternates with facies FI, this unit is a part of the top of sediment sequence. It contain burrows, rootlets and dessication cracks. This facies may be formed by finer sedimentation in high magnitudes in the waning flood stage.

2.3.3 Lithofacies Relationships, Their Implications

The lithofacies successions are characterised by the presence of a couple of fining upward sedimentation cycles. However, a typical cycle is rarely developed. Variation in grain sizes in the different lithounits is not that sharp. Beginning of a new cycle is marked by massive to horizontal bedded sands while the top portion is covered by massive mud with organic influence.

Finning upward cycles have been projected mostly as a product of fluvial influence (Allen, 1970; Walker and Cant, 1984; Miall, 1985). The basal massive sands along with the horizontal strata are products of the upper flow regime with high to moderate velocity currents of plane bed phase (Harms and Fahnestock, 1965; Picard and High, 1973). Going by the thickness of the massive and horizontally stratified sands, it appears that the upper flow regime prevailed for a longer extent of time. Cross bedded sands are believed to be formed by downstream migration of mega current ripples (Lane, 1963; Allen 1963a) under a stream flow of high intensity in the lower flow regime. Planar type is formed by down current migration of 2-dimensional ripples while 3-dimensional ones (dunes) are responsible for the trough cross stratifications. Genetically the trough cross stratification is related to lingoid type mega ripples. Harms and Fahnestock (1965) points out that this morphotype is indicative of low intensity current in the low flow regime. The rippled unit is also indicative of a lower flow regime. Typically during low water stage, the river water receeds and, only a thin sheet of water with high sediment input of
finer nature gets deposited. Bedform undulations or fluctuations in the strength of the depositional media etc. leads to the deposition of the same. Massive mud layers along with very fine grained laminated sand, silt and organic materials are products of deposition in the waning stages of a flood cycle mostly by vertical accretion. These layers mark the end of a flood cycle. Rare occurrences of organic materials, their concentrations may be attributed to a transitory stage in the flow regime.

Localised shift of flow direction of the media may lead to a swampy condition wherein high concentration of organic materials may take place. Such materials may in due course of time become a victim of the processes of coalification. In the present case, the process of coalification was incomplete and hence, only the poorest variety, i.e., peat type layer could be formed.

The present study gives a picture of the distribution of various facies as well as the water level conditions throughout the area. A hypothetical sedimentation model constructed for the generalised sedimentary sequences suggest rapid sedimentation and high energy conditions for the basal part of the column mostly of the upper flow regime. These are followed by facies like cross-stratification, trough cross-strata, rippled strata, finely laminated silts, muds etc indicating deposition in the wanning stages of a flood.

Facies observations indicate that majority of the sequences towards the base may be a product of braided river condition. The abundance of massive and horizontally stratified sands suggest the presence of an upper flow regime. The laminated fine sands along with muddy layers may also be interpreted as sediments filling abandoned chute channels. These chute channels are active only at the flood stage and these were the sediments deposited mainly from suspension mainly as overbank facies (Allen, 1985).

However, considering the nature of the finding of this project the present litholog of the study area may also be considered to have an influence of a distributary network of channels.
LITHOFACIES COLUMN OF THE SEDIMENTARY ROCKS EXPOSED IN AND AROUND SONAPUR

<table>
<thead>
<tr>
<th>THICKNESS (in metres)</th>
<th>LITHOFACIES LOG</th>
<th>GRAIN SIZE VARIATIONS</th>
<th>FACIES CODE</th>
<th>PRIMARY STRUCTURES</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 m</td>
<td></td>
<td></td>
<td>Fm</td>
<td>Very fine silt, clay, poorly laminated</td>
</tr>
<tr>
<td>0.85 m</td>
<td></td>
<td></td>
<td>C</td>
<td>Structureless black layer</td>
</tr>
<tr>
<td>7 m</td>
<td></td>
<td></td>
<td>Fl</td>
<td>Fine sand, silt, clay lamination</td>
</tr>
<tr>
<td>3 m</td>
<td></td>
<td></td>
<td>Sr</td>
<td>Fine sand rippled</td>
</tr>
<tr>
<td>3 m</td>
<td></td>
<td></td>
<td>St</td>
<td>Trough cross bedding</td>
</tr>
<tr>
<td>8 m</td>
<td></td>
<td></td>
<td>Sp</td>
<td>Planar cross bedding</td>
</tr>
<tr>
<td>28 m</td>
<td></td>
<td></td>
<td>Sh</td>
<td>Horizontally stratified sandy facies</td>
</tr>
<tr>
<td>20 m</td>
<td></td>
<td></td>
<td>Sm</td>
<td>Massive sandy facies</td>
</tr>
</tbody>
</table>
Plate no. 3: PHOTOGRAPH SHOWING MASSIVE NATURE OF SANDSTONES.

Plate no. 4: PHOTOGRAPH SHOWING STEEPLY DIPPING THICK AND CROSS-JOINTED SANDSTONES.
Plate no. 5: PHOTOGRAPH SHOWING PROMINENT AND CONTINUOUS LAMINATIONS IN THE SANDSTONES.

Plate no. 6: PHOTOGRAPH SHOWING POORLY DEVELOPED LAMINATIONS OF SHALE AND MUDSTONE.
Plate no.7: PHOTOGRAPH SHOWING POORLY DEVELOPED TROUGH CROSS-STRATIFICATION OF THE SANDSTONES.

Plate no.8: PHOTOGRAPH SHOWING AN EXOTIC BLOCK OF SANDSTONES HAVING PEBBLE AND GRANULE SOCKETS.
Plate no. 9: PHOTOGRAPH SHOWING POORLY DEVELOPED CROSS-BEDDING IN THE SANDSTONES.

Plate no. 10: PHOTOGRAPH SHOWING RIPPLE MARKS IN THE SANDSTONES.
Plate no. 11: PHOTOGRAPH SHOWING AN ALTERNATION OF SANDSTONE, SHALE AND CARBONACEOUS SHALE.

Plate no. 12: PHOTOGRAPH SHOWING A PATCH OF LOW GRADE COAL INTER-LIVED WITHIN ALTERNATIONS OF SANDSTONES AND SHALES.
Plate no. 13: PHOTOGRAPH SHOWING ALTERNATIONS OF MASSIVE TO POORLY LAMINATED SHALES AND MUDSTONES.

Plate no. 14: PHOTOGRAPH SHOWING ALTERNATIONS OF SANDSTONES AND SHALES WHERE THE SHALY PART IS HIGHLY WEATHERED AND LEACHED.