Chapter I

INTRODUCTION

1.1 RATIONALE OF THE STUDY

Constructing a precise stratigraphic framework for continental basins is often beset with problems because of the paucity of absolute chronological constrains as well as the absence of reliable chronostratigraphic markers. In foreland basins in particular, lithostratigraphic units generally have diachronous boundaries, rapid lateral facies transitions are frequent and therefore basin wide stratigraphic correlations are usually too uncertain for high resolution paleoenvironmental studies at basinal. In the present study an attempt has been made to determine magnetic polarity stratigraphy of the well exposed Bhuban and Tipam sections (Kolasib-Rengtekawn, Zero Point - Saihapui and Tuichhuahen sections of Mio-Pliocene age in Kolasib district of Mizoram), which lie in Tripura –Mizoram accretionary belt of the Chittagong-Tripura fold belt- a southern extension of Surma basin. The Surma is an outer arc basin within the greater Bengal Basin (Sarkar and Nandy, 1977; Ferdous and Renaut 1996; Mannan 2002). A magnetostratigraphic correlation on Mio-Pliocene Bhuban succession and Tipam Sandstone Formation in the Surma Basin have been established in the successions around Aizawl in Mizoram (Tiwari et al., 2007; Malsawma, 2010; Malsawma, 2011) and along the Hari River Section (Worm et al., 1998), which have been proved highly successful in redefining the chronostratigraphy of the Bhuban and Tipam succession of Mio-Pliocene age in the basin.

1.2 STUDY AREA

Mizoram is a north-eastern hill State of India situated at the borders of the Tripura State and Chittagong Hill tracts of Bangladesh in its west and the international boundary with Chin Hills of Myanmar in east. To its north is the Cachar district of Assam and Churachandpur district of Manipur. The State with a geographical area of about 21,081 square kilometers lies between 21°56’N to 24°31’N latitudes and 92°16’E to 93°26’E longitudes. It has maximum aerial dimensions of 285Km from north to south, and 115Km from east to west (Pachuau, 1994). Till 1972, it formed the
southern mountain district of the Assam state and it was accorded the status of the Union Territory with capital at Aizawl in the year 1972. It became a full-fledged state in 1986. The tropic of cancer passes through the state, dividing it almost into two equal parts. Mizoram is connected with Assam through National Highway - 54. This highway having a total length of 572 Kms connects Silchar (Assam) with Tuipang village in the southern corner of the state passes through Aizawl. It is also connected by air with Kolkata, Guwahati and Imphal.

A huge thickness of Tertiary sequences of the order of ~ 8000m is exposed in the state of Mizoram. This succession has been grouped into the Barail, the Surma and the Tipam Groups. Geologically, it is considered as the southern extension of Surma basin. In spite of huge thickness and good exposures, it has not yet been fully explored geologically rendering a vast scope for further researches in various aspects of earth sciences.

![Location map of the study area](image)

**Fig. 1.1.** Location map of the study area (studied sections shown within white rectangles 1-4).
The study area is around Kolasib and is covered by the Survey of India Topographic sheet Nos. 83 D/11 and 83 D/12 and lies within the coordinates of latitudes N 24° 17’ to N 24° 13’ and longitudes E 92° 37’ to E 92° 41’. The location map of the study area is shown in Figure 1.1.

1.3 PHYSIOGRAPHY AND CLIMATE

The hilly terrain of Mizoram is highly undulated and rugged consisting of alternating ridges and valleys that approximately trend N-S to NNE-SSW with a tendency to taper at both the ends. The terrain exhibits first order topography. The average elevation of the state is about 900 meters above Mean Sea Level. The elevation ranges from 40 meters at Bairabi (Mizoram-Assam border) to 2157 meters at Phawngpui (Blue Mountain) along the Myanmar border. Thus the general elevation increases from west to east. The hill ranges mainly comprise relatively compact and resistant older rock units exposed in the anticlinal crest, whereas the valleys are composed of younger and softer formations exposed in the synclinal troughs (Ganguly, 1983). Hills are generally characterized by steep slope, mostly anticlinal, trending approximately N – S, and are separated by synclinal narrow river valleys flowing either towards north or south forming deep gorges. These anticlines and synclines are intersected by transverse faults. The difference in elevation between valley floors and hilltops varies greatly from west to east ranging from 200m to 600m (Karunakaran, 1974).

The terrain is young and immature due to recent tectonism. It shows prominent relief and topographic features with steep slopes. The major geomorphic features are mostly erosional landforms comprising of structural and topographic ‘highs’ and ‘depressions’, ‘flats’ and ‘slopes’ that are arranged in linear fashion.

The area exhibits angular, sub-parallel, parallel and dendritic drainage patterns. Lower order streams run both parallel and across topographic ‘highs’ and ‘depressions’. Dhaleswari (Tlawng), Sonai (Tuirial) and Tuivawl are the major rivers that flow northerly. These rivers originate in the central part of the state and drain water into the Barak Valley of Assam indicating general slope direction towards the north. The important southerly flowing rivers are Koladyne (Chhimtuipui) and Karnafuli. The former is the biggest river in the state, originates from Myanmar and
flows southerly through a distance of about 500 km in Mizoram and enters Myanmar again. Karnafuli River originates at the southern tip of Mizoram, flows northerly up to the central part of the state, then takes turn towards west and enters into Bangladesh (Pachuau, 1994).

Mizoram experiences a moderate climate owing to its location in the tropical region. It has a humid climate characterized by short winters and long summers with heavy rainfall. The temperature varies from 11°C to 23°C during winter, 21°C to 35°C during summer and 18°C to 25°C during autumn season. The state is under the direct influence of southwest monsoon and experiences heavy rainfall. The onset of monsoon is in the month of May, lasting till late September. Mizoram has an annual average rainfall of 250 cm. The northwestern part of the state receives the highest rainfall averaging to 350 cm annually. The highest ever-recorded rainfall in Mizoram has been 602.60 cm during the month of July, 1983. Maximum rainfall generally takes place in the months of July and August while December and January are normally rain-free and form the driest months of the year (Tiwari, 1992).

1.4. FLORA AND FAUNA

The state is endowed with a very rich and diversified floral and faunal species because of the mingling of eastern floral and faunal species besides the North Indian ones. The entire state abounds in sub-tropical trees, plants, bushes, grasses and a variety of bamboos. Fern and allies, soft stemmed herbaceous plants, orchids and other epiphytes make a long list of plants endemic to this area and form a unique assemblage of non-tree floral species.

The forests in Mizoram houses a large variety of wild animals like tiger, leopard, sambhar, deer, bear, wild pig, mithun, mountain goat, flying squirrel, monkey, snakes and other reptiles.

1.5 REVIEW OF LITERATURE

The earliest comprehensive accounts pertaining to the regional stratigraphic framework of the Surma basin inclusive of the Bengal basin is made by Evans, (1932). The tectonic scenario has later been described by Evans, (1964); Sengupta, (1966) and Raju,(1968) contributing to the fundamental understanding of the basin generation and
sediment-fill history. Bakhtine (1966) outlined the tectonic elements within the Bangladesh part of the basin for the first time. Subsequently, Alam (1972) described the geological evolution of the basin in terms of the then popular geosynclinal model. Desikacher (1974) reviewed the geological history of eastern India in the light of plate tectonic theory. This was followed by the work on plate tectonic scenario for evolution of the basin within the broader context of the Southeast Asia region (Curry and Moore, 1974; Graham et al., 1975; Paul and Lian, 1975 and Curry et al., 1982).

Considerable subsurface data have been generated during the last two decades due to activities related to the hydrocarbon exploration (e.g. Salt et al., 1986; Murphy and Staff BOGMC, 1988; Lindsay et al., 1991; Reimann, 1993; Lohmann, 1995; Shamsuddin and Abdullah, 1997; Uddin and Lundberg, 1999), that has enriched our current understanding of the Bengal Basin configuration. In addition, Alam (1989, 1997) discussed the overall stratigraphic and tectonic history of the basin. Johnson and Alam (1991) described the sedimentation and tectonics of the Sylhet Trough in the northeastern part of the basin. Alam (1995a) demonstrated the tide-dominated shallow marine sedimentation in the Miocene rocks in the south-eastern Bengal Basin. Describing the deep-water clastics from the south-eastern part of the basin, recently Gani and Alam (1999) have partly refined the conventional thinking regarding the sedimentation and tectonics of the basin, particularly the Chittagong–Tripura Fold Belt (CTFB) region.

Most workers agree that the region records the accretion of several plates and platelets of Gondwana affinity (Falvey, 1974; Varga, 1997). It is believed that India rifted from the combined Antarctica–Australia part of Gondwanaland and began its spectacular journey, initially northwestward and then northward, sometime in the Early Cretaceous (Curry and Moore, 1974; Curry et al., 1982; Hutchison, 1989; Lee and Lawver, 1995; Acharyya, 1998; and others). Thick sediment cover in the Bengal Basin conceals the basement configuration and makes the reconstruction or exact location of plate boundaries and sutures more difficult. Plate movement patterns and evolution of the Bengal Basin and the Bay of Bengal are carried out mostly with data and interpretation from the Indian Ocean, following early work by McKenzie and Sclater (1971), Sclater and Fisher (1974) and others. One of the problems of plate reconstruction for the Indian Subcontinent is determining the eastern limit of Indian continental crust. Most of the earlier plate reconstruction scenarios (Curry and
Moore, 1974; Graham et al., 1975; Curray et al., 1982) considered the eastern limit of the Indian continental crust to be approximately along the Hinge Zone, which lies above the Calcutta–Mymensingh Gravity High, with the oceanic part of the Indian Plate subducting beneath the Indo-Burman Ranges west of the Burma Block (the ‘Mt. Victoria Land Block’ of Mitchell, 1989; the Indo-Burma-Andaman or IBA Block of Acharyya, 1994, 1998; or the West Burma Block of Hutchison, 1989). They all considered the Burma Block to be of continental origin from Gondwana. Murphy and Staff BOGMC (1988) and BOGMC (1997) show the area between the Hinge Zone and Barisal–Chandpur Gravity High to be attenuated or thinned continental crust, so that the continent–ocean crust boundary lies along the Barisal–Chandpur Gravity High (Fig. 2a and b). Acharyya (1998) places the present subduction zone on the western side of the Chittagong Hill Tracts (i.e. the CTFB), in the middle of the Bengal Foredeep or the deep basin. Mukhopadhyay and Dasgupta (1988) however states that this is certainly the deformation front of the subduction zone, although the underlying crust and lithosphere do not descend rapidly until much farther east. Ophiolite on the eastern side of Mt. Victoria is explained by Hutchison (1989) and Mitchell (1989) as a suture formed during eastward subduction; by Mitchell (1993) as a suture formed by westward subduction; and by Acharyya (1998), not as a suture, but instead as a flat-lying klippen rooted in the IBA (Indo-Burma-Andaman)-SIBUMASU (Siam, Burma, Malaysia and Sumatra) suture lying farther to the east beneath the central Burma Basin.

The area under study belongs to Bhuban sediments of Surma Group (Neogene age). No detailed magnetostratigraphic or palaeomagnetic work is available for these sedimentary sequences. However, reasonably good amount of work has been carried out on these aspects in the equivalent sequences of the Himalayan region. Unquestionably, the best studied area in the Himalayan region is the continental Neogene vertebrate bearing Siwalik sediments of India and Pakistan. These studies began in the mid-1970 and have continued till present [Opdyke et al., 1982, Johnson et al., 1983, Tandon et al., 1984, Ranga Rao et al., 1988, Ranga Rao 1993, Opdyke and Channell 1996, Sangode et al., 1996, 1997, 1999, 2001, 2003 and Sangode and Bloemendal 2004]. The region is wonderfully suited for magnetic stratigraphy because of well-exposed long sections of highly fossiliferous sediments that became magnetized early in their history. In this region it is possible to begin with the Brunhes Normal age sediments (0.5 Ma onwards) and systematically work back in time to the
onset of sedimentation in the basin (Keller et al., 1977, Opdyke et al., 1979 and 1982, Johnson et al., 1982 and 1985 and Tauxe and Opdyke 1982). In many respects, the area served as a laboratory for the application of magnetic stratigraphy to (1) Vertebrate evolution and migration (Flynn et al., 1984). (2) Sedimentary processes (Raynolds and Johnson, 1985; Berhrensmeyer and Tauxe, 1982), (3) Tectonics (Burbank and Raynolds, 1988), and (4) Basin development (Cerveny et al., 1988). Almost all these applications of magnetic stratigraphy to terrestrial sediments were anticipated by Johnson et al. (1975). In the Siwaliks, the magnetic stratigraphy is now well known from multiple sections that vertebrate paleontologists usually correlate new fossil finds directly to a nearby magnetic stratigraphy and hence to the Global Polarity Time Scale (GPTS).

The existing stratigraphic scheme of the Bengal Basin was originally established on the basis of the exposures along the fold belt in the eastern part of the basin and their purely lithostratigraphic correlation with the type sections in Assam, north-eastern India, described by Evans (1932). The stratigraphic age assignments given by Evans for the Assam sequences are by no means reliable because they were based on long distance correlations of brackish marine macro fauna and vertebrate finds. While some parts of Evans’ scheme may be usable in the regional lithostratigraphic or seismic correlation (e.g. the boundary between the Surma and Tipam Groups), other parts of his classification (e.g. the contact between the Bhuban and Bokabil Formations or the internal units of these formations) are difficult to apply to the lithostratigraphic succession throughout the basin. Therefore, over the years several workers have attempted to refine this scheme on the basis of palynological studies (e.g. Chowdhury, 1982; Uddin and Ahmed, 1989; Reimann, 1993); micro paleontological studies (Ahmed, 1968); and seismo-stratigraphic studies (Lietz and Kabir, 1982; Salt et al., 1986; Lindsay et al., 1991). Following Evans’ (1932) stratigraphic scheme, the Surma Group has traditionally been divided by workers in Bangladesh into two units—a lower Bhuban and an upper Bokabil Formations (e.g. Holtrop and Keizer, 1970; Hiller and Elahi, 1988; Khan et al., 1988; and others) throughout the Bengal Basin. However, Johnson and Alam (1991) consider the group as a single stratigraphic unit because they observed no significant lithologic and petrologic differences between these formations. Khan, (1991) also considers the group as a single unit based on the lithological similarity and lateral facies variations
within the group. Alam et al. (2003) suggest that on the basis of the presence of a prominent seismic marker within the Surma Group (Hiller and Elahi, 1988), the group may informally be divided into a lower and an upper unit. They further indicate that the divisions of the Surma Group in the Sylhet Trough are independent of the Bhuban and Bokabil divisions of the group in the Assam Basin. Similarly, Lee et al. (2001) divided the Surma Group into two formations on the basis of a seismic marker defined as maximum flooding surface. The problem of facies variations within the Surma Group has been noted by Banerji (1984), who observed that rocks of the group from different outcrops and subsurface sections show variable conditions of deposition ranging from open marine to interdeltaic types. It appears from earlier works (Banerji, 1984; Khan et al., 1988; Reimann, 1993; Zahid, 2005) that facies variations associated with alternating cycles of marine transgressions were of variable extent and affected by localized regressive phases; and therefore subdivision of the group over a wider area based on sand/shale ratio alone is probably prone to miscorrelation (Alderson, 1991). The top of the group constitutes a predominantly shaly unit, designated as the ‘Upper Marine Shale’ (Holtrop and Keizer, 1970), which represents a 230-m thick pelitic sequence marking the last marine incursion, and is probably the sole seismic marker horizon throughout the Sylhet Trough.

Thickness of the Surma Group varies from 2700 m to over 3900 m in various wells in Bangladesh (Alam et al., 2003), which is in good concurrence with the thickness of 2800–3250 m in the Naga Hills to the east (Rao, 1983). Johnson and Alam (1991) have interpreted the lower Surma Group (i.e. Bhuban Formation) as prodelta and delta-front deposits of a mud-rich delta system similar to the modern Bengal delta. The sediments of the upper Surma Group (i.e. Boka Bil Formation) represent deposits of subaerial to brackish environments, based on mudrocks and pollen types (Holtrop and Keizer, 1970; Alderson (1991) noted marine influence within the Boka Bil Formation in eastern Sylhet Trough. On the basis of detailed facies analysis of core samples and wireline log interpretation, Alam (1995b) envisaged a micro-tidal coastal setting with extensive development of intertidal and subtidal environments within a proto-Surma delta embayment, for the Surma Group sediments in the Sylhet Trough. Similarly, on the basis of comprehensive logging of the core samples from the Sylhet Trough, Sultana and Alam (2001) have interpreted
the sediment of the group as deposits of environments ranging from shallow marine to
tide-dominated coastal settings within a cyclic transgressive–regressive regime.

The Surma Group is overlain unconformably by the Middle Pliocene Tipam
Group, consisting of the Tipam Sandstone and Girujan Clay Formations. The Tipam Sandstone comprises coarse-grained, cross-bedded sand and pebbly sand, with common carbonized wood fragments and coal interbeds; and interpreted as deposits of bed-load dominated braided-fluvial systems (Johnson and Alam, 1991). The Girujan Clay, composed mainly of mottled clay, accumulated in subaerial conditions as lacustrine and fluvial overbank deposits (Reimann, 1993). Sedimentological aspects of Cenozoic succession of varied depositional environment from Himalayan region are fairly well studied (e.g. Raiverman and Raman, 1971; Samanta et al. (1993). Such studies in the Tripura–Mizoram accretionary belt are however meager. Holtrop and Keiizer (1969) made an attempt to classify and sub-divide the Surma sediments occurring below the Bangladesh Alluvial Plain by sand/shale ratio. Sinha and Sastry (1972) analysed the heavy minerals from the exposed Surma rocks of Cachar and Tripura Hills with a view to classify and sub-divide them. Detailed study on these aspects is however required for evolving any meaningful scheme of classification of Surma rocks. More recently, Uddin and Lundberg (1998) carried out detailed heavy mineral study of Surma sediments from the Bengal basin and concluded that Surma sediments had an orogenic source both from the Eastern Himalayan region and Indo-Burman ranges. As such detailed sedimentological study of Bhuban sequence of Tripura-Mizoram accretionary belt is highly desirable. Badekar et al. (2011) studied lithostratigraphy of 1618m succession belong to Middle and Upper Bhuban units of Bhuban Formation and inferred a gradual marine to deltaic and continental transition under prograding depocentre.

Recently, Tiwari et al. (2007) studied a 560m thick rock succession of Middle Bhutan unit (Surma Group) exposed between Bawngkawn and Durtlang, Aizawl, Mizoram producing age constrains at sub formation level. They delineated 7 normal and 7 reverse magneto-zones in this section. The GPTS correlated ages of this section lie between ~21.77 Ma (at the base) to ~15.16 Ma (at the top) with a total duration of ~ 6.6 Ma. The average sediment accumulation rate (SAR) estimated for this section is 8.48 cm/Ka. Paul (2006) studied magnetostratigraphy of Chanmari-Chaltlang section in Aizawl and delineated 3 normal magnetozones in the 137m rock succession belonging to Middle Bhutan unit exposed in this section. Further, Malsawma et al. (2010) studied a 1355 m thick Bhutan sequence exposed along Tuirial section in the Aizawl district, Mizoram has been studied for magnetostratigraphic and rock magnetic attributes. The study reveals mono-mineral nature of the rocks with magnetite in the range of Stable Single Domain (SSD) showing the most favorable mineralogy to produce authentic (Natural Remanent Magnetization) NRM directions. Using routine demagnetization methods we reveal a total of 7 normal magneto-zones in the studied part of the Tuirial section. Correlation of the observed polarity with GPTS gives ages ~12.5 Ma to ~8 Ma. A notable increase in the rate of sedimentation at ~9.5 Ma (~750 m level in the section) indicates facies change from turbidities like sequence to pro-delta system (Malsawma, 2011).

Table 1.1. Stratigraphic succession of Mizoram.

<table>
<thead>
<tr>
<th>Age</th>
<th>Group</th>
<th>Formation</th>
<th>Unit</th>
<th>Thickness (m)</th>
<th>General Lithology</th>
<th>Depositional Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recent</td>
<td>Alluvium</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Silt, clay &amp; gravel</td>
<td>River deposits</td>
</tr>
<tr>
<td>Early Pliocene</td>
<td>Tipam</td>
<td>-</td>
<td>-</td>
<td>+900</td>
<td>Friable sandstone with occasional clay bands</td>
<td>Stream deposits</td>
</tr>
<tr>
<td>to Late Miocene</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Miocene to Upper</td>
<td>Bokabil</td>
<td>Upper</td>
<td>-</td>
<td>+950</td>
<td>Shales with siltstone and sandstone</td>
<td>Shallow marine</td>
</tr>
<tr>
<td>Oligocene</td>
<td></td>
<td>Bhuban</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SURMA</td>
<td>Upper Bhuban</td>
<td>-</td>
<td>+1100</td>
<td>Arenaceous with sandstone, shales and siltstone</td>
<td>Shallow marine, near shore to lagoonal</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Middle Bhuban</td>
<td>-</td>
<td>+3000</td>
<td>Argillaceous with shales, siltstones</td>
<td>Deltaic complex</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lower Bhuban</td>
<td>-</td>
<td>+900</td>
<td>Arenaceous with sandstone, shales and siltstone</td>
<td>Shallow marine</td>
<td></td>
</tr>
<tr>
<td>Oligocene</td>
<td>Barail</td>
<td>-</td>
<td>+3000</td>
<td>Shales, siltstone and sandstones</td>
<td>Shallow marine</td>
<td></td>
</tr>
<tr>
<td>Data source</td>
<td>Karunakaran, 1974; Ganju, 1975</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
A total of 4 normal magneto-zones were obtained in the Sairang section, Aizawl by Malsawma (2011) and the GPTS correlated ages of the Sairang section falls between ~9.8 Ma to ~8.3 Ma. He estimates a total of ~1.5 Ma duration for the accumulation of 460 m thick sedimentary pile in this section. Average sedimentation rate as worked out by him for this section is 30.17 cm/ka.

1.6 SCOPE OF PRESENT WORK

Chronostratigraphic correlation of the exposed sediments is one of the most fundamental aspects in geological investigation of this basin. However, this sedimentary sequence is devoid of age-diagnostic fauna as marker horizons limiting the classical stratigraphic approach. The sequence from Bhuban to Tipam represents a major change in depositional environments from marine to transitional to continental. However there is no clear stratigraphic and age control for this sequence and limited magnetostratigraphic attempts were made. Magnetostratigraphy, being independent of such lithostratigraphic constraints, is anticipated provide a robust tool of basin wide stratigraphic correlation. Magnetostratigraphy has been successfully used throughout the globe in varied depositional environment and is particularly well exercised in the adjoining Himalayan foreland basin. Previously, magnetostratigraphy was also used successfully in the Middle and Upper Bhuban units of Bhuban Formation of Surma basin by Tiwari et al., 2007; Paul, 2006; Malsawma et al., 2010, Malsawma, 2011). Therefore the present work is an attempt to determine magnetic polarity stratigraphy of the well exposed Bhuban and Tipam sections (Kolasib-Rengtekawn, Zero Point - Saihapui and Tuichhuahen sections of Mio-Pliocene age in Kolasib district of Mizoram, (Figs. 1.1 and 1.2) representing marine to transitional to continental succession to provide the stratigraphic controls for further correlation.

1.7 AIMS AND OBJECTIVES

Aimed at developing a robust chronostratigraphic database for the Surma basin rocks, present work was planned to address the following issues in a part of the Mizoram fold belt.

- Nature of magnetization and magnetic polarity preserved in the study area and its suitability to detailed chrono-stratigraphic approach.
• Integration of magnetic with the litho- and biostratigraphic database from the area.

• Estimation of rate of sedimentation and its possible relation to the evolution of Surma basin during Late Miocene to Pliocene time window.

With above aims, the research proposal was evolved to address the following objectives:

• To work out the magnetostratigraphy in the transition from Surma to Tipam Groups.
• To estimate the rate of sedimentation, and
• To establish stratigraphic correlation in regional perspective.

1.8 METHODOLOGY

The present study is systematically carried out adopting the following research methodology.

1.8.1 Literature Survey

Collection, survey and critical reading of the relevant literature on sedimentology, palaeomagnetism, stratigraphy, magnetostratigraphy, regional geology and geology of the area pertaining to the research problem. This was achieved through visiting the libraries of the Geological Survey of India at Kolkata and Lucknow, Wadia Institute of Himalayan Geology, Dehradun and Department of Geology, University of Lucknow, Lucknow, University of Pune. Additionally, literature has also been downloaded from the internet. Preparing notes on critical aspects and discussion with experts was also made during the literature survey.

1.8.2 Fieldwork

Geological map of Mizoram prepared by Ganju (1975) and Nandy (1983) has been used as a base map for field work in the study area. Extensive field work was carried out along several road and nallah sections, and quarry sites. All the necessary field information was noted over the toposheets of the area in order to compile the geological map, study the sedimentologic variations and correlate them. Detailed
lithocolumns were prepared by measuring each and every bed in the selected section using tape and compass. This was followed by the systematic sampling in the representative sections for magnetostratigraphy.

### 1.8.3 Laboratory work

Since the magnetic methods principally deal with directions, the samples are to be oriented to its natural positions with the compass north. Thus the oriented block samples using standard palaeomagnetic methods (Collinson, 1983) were collected for magnetostraigraphic and the representative rock magnetic study. The samples were then re-aligned in the laboratory to their field positions and drilled to get 2.5 cm (dia) x 2.2 cm height cylindrical specimens. Since the study involves both the natural and laboratory induced remanence to reveal the ancient magnetic field directions and intensities, and the magnetic mineralogy; the experiments were made separately for both these approaches. Initially the magnetic mineralogy is established based on the Isothermal Remanent Magnetization (IRM) and Anhysteretic Remanence Magnetization (ARM) experiments using an Impulse Magnetizer and ARM attachment to Alternating Field Demagnetizer (AFD). Magnetic susceptibility was measured using the dual frequency magnetic susceptibility meter (MS-2 of Bartington) to find the volume and mass specific susceptibilities and their frequency-dependence.

The magnetostratigraphic analysis was divided into several phases starting with a pilot study on representative samples, followed by collection of more samples in first phase. This enabled to decide the demagnetization strategy to reveal the reliable directions. During phase II and phase III detailed sampling was done in both the section to build the local polarity pattern. Final phase of sampling was conducted to fill the larger gaps and to check some of the crucial boundaries of the magneto-zones. The details on principles and the magnetostratigraphic methods applied, the demagnetization strategy, results and interpretation are elaborated in Chapter 5 in this thesis.
Fig. 1.2. Panoramic view of the studied sections in Kolasib District of Mizoram. A. Kolasib-Rengtekawn section representing Middle and Upper Bhuban succession. B. Zero Point part of Zero Point – Saihapui section representing Bokabil to Tipam transition. C. Saihapui part of Zero Point – Saihapui section representing Tipam succession. D. Tuichhuahen section representing Tipam succession.
Chapter II

GEOLOGICAL FRAMEWORK AND TECTONIC SETTING

2.1 REGIONAL GEOLOGICAL SETUP

Proper understanding of regional geological framework is necessary in order to know the provenance, depositional setting, and post-depositional changes with reference to a given sedimentary basin. These factors can variably influence the palaeomagnetic records in the form of contribution to natural remanent magnetization (NRM) as well as tilting and rotation of the primary components. As a result, the magnetostratigraphic records are controlled by several basin tectonic factors, such as varied rates of sedimentation, migration of depo-centres, and change in subsidence rates. Comprehensive description of the regional geology is therefore, essential in order to envisage these factors.

It is essential to view the greater Bengal Basin in its regional perspective in order to comprehend the paleo-tectonic history of the basin. Regional geological setup of the study area is formed by the 2500 long, 300 km wide east-west trending Himalaya and the 1500 km long 230 km wide north-south belt of the Indo-Myanmar ranges formed as India collided with Eurasian and the Burmese plates. Regional geologic set up can be distinguished into three main parts, namely, the Indian craton, the Indo-Myanmar ranges and the Bengal Basin (Fig. 2.1).

2.2 INDIAN CRATON

The timing of initial collision of the Indian plate with Eurasia is debatable. However, it has widely been considered that the time of initial rifting of the Indian continent from the East Gondwana block occurred during Cretaceous (Curry and Moore, 1974; Acharyya, 1986; Hutchison, 1989). There were two episodes of extensive continental flood basalt extrusion, namely, Rajmahal (~118 Ma; Kent et al., 2002) and Deccan (70-65 Ma, Mahoney et al., 1985). The Rajmahal trap comprises two units: trap flows and intertrappean sediments.
Fig. 2.1. Map showing major tectonic elements in and around the Bengal basin. The Dauki Fault separates the Sylhet trough from the uplifted Shillong Plateau to the north. Cross-sections along E-W, N-S and E-W are shown in Fig. 2.5a-b (after Uddin and Lundberg, 1998).

The trap flows are basaltic in composition; they are hard, crystalline to cryptocrystalline, usually porphyritic, and vesicular. The intertrappean sediments consist of fine-to medium-grained massive sandstones, and medium to dark gray, micaceous and carbonaceous shales with thin bands of shaly coal and coal
The Deccan trap exposed in west-Central India is a thick (~2000 m exposed) sequence of flat-lying tholeiitic lava flows that presently cover an area of nearly 500,000 km.

The eruption of this large volume of basaltic rocks took place within a short time span, from the end of Cretaceous to the very Early Tertiary (Mahoney et al., 1985). Rift-drift episodes associated with the Paleo-Mesozoic break-up of Gondwanaland created continental blocks, which were located within the Tethyan Ocean (Curray et al., 1982). These Gondwanic blocks were accreted to the Asian collage by collisional processes. The Indian block collided terminally with the Tibetan block during Early-Middle Eocene, initiating the Himalayan orogenesis (Dasgupta and Nandy, 1995). The Bengal Basin is bounded by the Indian Craton to the west (Fig. 2.1). The Indian crust has a composite mosaic-type structure that includes remnants of an Archean gneissic complex (Rahman, 1999). The Bengal basin is bounded to the north by thenortheastern extension of Indian craton, the Shillong plateau. This plateau was uplifted to its present height (average 1 km, maximum 2 km) in the Pliocene (Johnson and NurAlam, 1991). The Shillong plateau is bounded to the west by the Garo-Rajmahal trough fault and to the south by the Dauki fault (Johnson and NurAlam, 1991). Late Mesozoic and Cenozoic sedimentary rocks drape portions of the southern Shillong plateau and generally dip south in a monocline. As much as 15-18 km of structural relief between the Shillong plateau and the basement of the Sylhet trough has been postulated (Hiller and Elahi, 1988). The poorly exposed Dauki fault forms the contact between the Shillong plateau and the Sylhet trough (Fig. 2.5a). This fault has a nearly straight face across essentially flat topography. The 5-km-wide fault zone is characterized by extensive fracturing (Evans, 1964) and near vertical (858) dips of Pliocene and Pleistocene strata (Khan, 1978). The Precambrian rocks of the Shillong plateau belong to two groups: (1) an Archean gneissic complex; and (2) the Proterozoic Shillong Group. The gneissic complex, exposed in the northern and western part of the plateau, consists of quartzo-feldspathic gneiss and schists (Rahman, 1999). The boundary between the Gneissic complex and Shillong Group is marked by a lithologic as well as structural break. The Proterozoic rocks have undergone regional metamorphism up to garnet-grade prior to the igneous activity in the area. The Shillong Group was overlain by Mesozoic to Miocene rocks prior to the Pliocene uplift of the Shillong plateau (Johnson and NurAlam, 1991).
2.3  INDO-BURMAN RANGES (IBR)

The collision of the Indian and Eurasian plates is represented by the Indo-Burmese Ranges along the eastern margin of the Indian sub-continent. The Indo-Burmese Ranges consist principally of early Tertiary synorogenic sequences, which have been deformed into imbricate thrust zones, and is a prominent geotectonic element of South Asia. The generally north-south-trending Indo-Burmese Ranges is an active orogenic belt that comprises a folded, thrusted and wrench-faulted outer arc complex, or accretionary prism, that accreted to the edge of the Eurasian Plate beginning the Jurassic (Graham et al., 1975; Ranga Rao, 1983). The ranges extend from the southern tip of the Mishmi Hills into southwest China and have an average width of 230 km. Mitchell (1981) divided the ranges into two orogenic belts: the western belt, comprising the Cretaceous to Eocene sedimentary rocks; and the eastern belt, consisting of schist’s and turbidites (Mitchell, 1993; Fig. 2.2). The eastern belt is locally overthrust by serpentinized harzburgites with pillow lavas and hornblende gabbros. Miocene sediments unconformably rest on the Eocene rocks along the west coast of Arakan in the eastern belt of Indo-Burmese Ranges. Several authors (Mitchell, 1993; Dasgupta and Nandy, 1995) have suggested that the Indo-Burmese Ranges were trench deposits containing ophiolitic mélanges scrapped off the Indian plate.

2.4  BENGAL BASIN

Geologic evolution of the Bengal Basin starting from Upper Palaeozoic time directly related with the break-up of eastern Gondwanaland and collision of the Indian plate with the Asian plate, can be divided into four major stages. I. Permo-carboniferous pre-breakup stage, II. Early Cretaceous Rift stage, III. Late Cretaceous-Eocene Plate or drift stage, and IV. Oligocene-Holocene Orogenic stage. The sedimentary cover of the basin with a maximum thickness of 20 km includes three major lithostratigraphic units separated by three major unconformities. The western part of Bangladesh is the platform shelf, whereas the eastern part of the country is represented by the folded belt (Chittagong-Tripura Fold Belt). The central part representing the most subsided part of the basin comprises two major depressions at the north (Sylhet Trough) and south (Patuakhali Depression).
Fig 2.2. Schematic composite cross-section through Mt. Victoria in eastern Indo-Burman Ranges and part of western limb of fore-arc basin syncline, Western Trough. a) Biotite- and biotite-graphite schist; b) Carnian quartzose turbidites, carbonaceous mudstones, minor limestone, recumbently folded and mostly forming broken beds; c) Serpentinized harzburgite; d) pillow basalt with included blocks of Triassic flysch; e) ammonite-bearing carbonaceous limestone, pyritic mudstones; f) Maastrichtian Paunggyi Conglomerate overlying Albion limestone, serpentinite and Triassic rocks; g) Boulder beds with granodiorite. Dacite clasts; h) Lower Eocene shallow marine limestones; i) Lower Eocene langushe shales and Tilin sandstones; j) house-size blocks of Triassic sandstone, Senonian micritic limestone, bedded chert, basalt, gabbro, within Paunggyi Conglomerate zone; k) Lower Eocene feldspathic turbidites grits, mudstones, with blocks of j; l) feldspathic sandstone and shale, with post-palaeocene fossils, occupying syncline (Modified from Mitchell, 1984).

The transition zone from the shelf to basin is represented by the hinge zone-at Eocene shelf/slope break (Fig.2.1). Rapid subsidence of the foredeep of the Bengal Basin was compensated by the influx of huge amounts of detritus originating from the nearby sources of the basin. Shallow water conditions and deltaic environment persisted. In addition to the western and northern foreland shelves, which were source areas earlier, the rising chains of the Himalaya and the Indo-Myanmar Ranges were
increasingly subjected to erosion and supplied much of the sediments since the mid-Miocene in the basinal area (Shamsuddin and Abdullah, 1997).

The Bengal basin, formed by rifting from passive continental margin, is gradually closing due to plate collision and orogeny along its eastern and northern margins (Rowley, 1996). The basin has been filled by an extremely thick accumulation of mostly clastic sediments which reach a maximum thickness of 20 km in the deeper part of the basin. The Bengal basin has two broad tectonic provinces: (1) the Indian platform, where thin sedimentary strata overlie rocks of the Indian craton in the northwest (in northwestern part of Bangladesh); and (2) a very thick basin-fill that overlies deeply subsided basement of undetermined origin in the south and east (Bakhtine, 1966; Khandoker, 1989). These two provinces are separated by a northeast-trending hinge zone (Fig. 2.1). Indian continental crust extends beyond the hinge zone toward the southeast (Khandoker, 1989).

The eastern fold belt marks the outermost part of the zone of compression between the west Burma block and the Indian plate. The north-south-trending folds in this belt decreases in amplitude and become broader and less complex westwards. Intensity of folding rapidly attenuates westwards; the central and western parts of the basin are relatively undeformed. Some structures show evidence of more than one phase of deformation. The age of folding ranges from the Pliocene to Recent. The Sylhet trough is a sub-basin of the Bengal basin in northeastern Bangladesh. It is characterized by a large, closed, negative gravity anomaly. The Sylhet trough has minimal topography and is actively subsiding (Holtrop and Keizer, 1970). The estimates of sediment thickness in the Sylhet trough range from about 12 to 16 km (Hiller and Elahi, 1984). The eastern part of the Sylhet trough lies in the frontal zone of the Indo-Burman Ranges.

The structural evolution of Chittagong-Tripura Fold Belt Basin (Fig. 2.3) is believed to have been largely controlled by the accretionary prism development and major east-dipping thrust faults produced by off-scraping of the oceanic sediments as a result of oblique subduction of the Indian plate beneath the Burma plate in an arc-trench setting (Gani and Alam, 1999). Within major individual thrust sheets, the sediments in the upper part have been deformed by the process of thin-skinned tectonics giving rise to a series of elongate, north–south trending curvilinear anticlines.
and synclines in this province; Sikder and Alam, 2003). Lohmann (1995) and Sikder (1998) have pointed out some duplex structures in the western part of Chittagong-Tripura Fold Belt. They have also suggested thin-skinned detachment and shear-off tectonics to explain the structural style of the region, but did not relate these processes directly to the subduction complex. We believe that the tectonic and structural development of Chittagong-Tripura Fold Belt may more readily be explained by the accretionary prism formation. Compressive (north–south) wrench tectonics, as a result of convergent-oblique movement of the Indian plate relative to the Burma plate, and the opening of the Andaman Sea during Miocene time has significantly influenced the overall structural architecture of the region (Murphy and Staff BOGMC, 1988; Sikder, 1998). It is anticipated that future identification of the major individual thrust sheets (accretionary wedges) will provide vital information in determining the chronological order of the Tertiary rock succession in the region, since it is well known that the accretionary complex as a whole youngs towards the west (Dasgupta and Nandy, 1995; Gani and Alam, 1999). Intuitively, one such major thrust, the Kaladan thrust in the east of CTFB (Fig. 2.1), has recently been described by Sikder (1998), but its significance is yet to be known.

**Fig. 2.3.** Schematic cross-sectional profile through the Chittagong–Tripura Fold Belt Province (see Fig.2.1 for location of the section line) showing the structural elements and development of Neogene accretionary prism complex resulting from the process of thin-skinned tectonics (after Sikder and Alam, 2003).
2.5 SURMA BASIN

The Neogene Surma basin is bounded by the post-Barail unconformity, subsequently faulted (Kaladan fault) to the east; the E-W Dauki fault and NE-SW Disang thrust to the north and northeast; the NE-SW Sylhet fault (Nandy et al., 1983), also term as the ‘Hail – Hakula’ (Ganguly, 1993) lineament and Barisal-Chandpur high concealed below the alluvium of Bangladesh (Sengupta, 1966) to the west and north west. To the south the basin is extended upto the Arakan coastal area of Myanmar. Within this vast terrain the surma group and the younger sediments occur as westerly convex N-S fold belt for a strike length of about 550 km, having a maximum width of 200 km. The surma basin covers lower Assam, Tripura, Mizoram, western part of Manipur, Sylhet and Chittagong districts of Bangladesh and Arakan coastal zone of Myanmar. To the east of this basin lies the intricately folded, faulted and thrust Palaeogene outer arc complex of the Indo-Myanmar mobile belt, where as to the west occurs the alluvium covered, gently dipping, homoclinal Tertiary sedimentary succession of Bangladesh (Bengal Basin). This assumed a ‘bell shaped’ form having constant southerly and south-westerly palaeoslope, and was connected to the open sea to the south.

2.6. SEDIMENTATION HISTORY OF BENGAL BASIN

The stratigraphy of the basin (Fig.2.4) is incompletely known because of thick sequences of alluvium cover and relative paucity of fossils. Comparative lithological studies have been the only means to establish and to interpret the stratigraphy. The nomenclature and classification of the stratigraphy of the Bengal basin is established on the basis of type sections in the Assam basin (northeast India) (Khan and Muminullah, 1980). Stratigraphically, only the Tertiary rocks are exposed in the folded flank of the Bengal basin (Chittagong Hills and flanks of the Sylhet trough; (Fig.2.4) and the Permo–Carboniferous Gondwana coals are the oldest Phanerozoic sediments at the holes drilled into the Precambrian ‘Indian platform’ tectonic zone in north west Bengal basin. These intracratonic, fault-Bounded Gondwana coal deposits are exposed at the western fringe of the Bengal basin, in the Bihar State of India. There are also subsurface occurrences of volcanic rocks, equivalent to the Rajmahal traps of India, followed by trap-wash sediments present above the Gondwana coal formations at the NW of the Bengal basin. Repeated submergence and emergence of the Bengal basin
must have taken place in the shelf region during Late Cretaceous–Middle Eocene time, when the deeper parts of the Stable shelf of West Bengal, Bangladesh and Assam were invaded by the sea, where as fresh water sedimentation of sandstone and carbonaceous mud rocks continued in most of the shallow shelf regions (Hoque, 1974; Banerji, 1981; Reimann, 1993). In the Bengal foreland and Indo-Burmese ranges, sedimentation took place in a marine environment and turbidites probably played an important role in sedimentation (Graham et al., 1975). The Eocene interval is marked by an extensive marine transgression caused by conspicuous basin-wide subsidence. Clastic sediment input on the ‘Stable shelf’ was reduced and the shelf became the site of deposition of shallow, clear water, open marine, limestone. These limestone’s, commonly known as the Sylhet Limestone, are very rich in fossil nummulites. This limestone is exposed at the northern fringe of the Sylhet trough on the south slope of the Shillong plateau.

The Oligocene to Earliest Miocene time was characterized by a major marine regression exposing most of the ‘Stable shelf.’ The Bengal basin is bounded from the Burma basin to the east by the Indo–Burmese ranges. The Oligocene clastic rocks (Barail Group) are exposed in part of the Sylhet trough and drilled in some holes (Holtrop and Keizer, 1970; Reimann, 1993). The Miocene Surma Group is a diachronous unit consisting of a succession of alternating mudrock, sandstone, siltstone and sandy shales with occasional thin conglomerates (Imam and Shaw, 1985). Overlying the Surma Group, the Upper Marine Shale represents a regional marine transgression in the region (Holtrop and Keizer, 1970). By Early Miocene time, a major phase of sedimentation started and huge amounts of clastic sediment were funnelled in to the basin from the north east and the major Mio-Pliocene delta complex started to build from the northeast (Uddin, 1990). A considerable amount of sediment was also coming in to the basin from the North West and small deltas were building on the western side of the basin (Alam, 1989). Sedimentation was in deltaic and open-shelf environments along the basin margins, whereas turbidites were controlling the sedimentation in the central and southern areas (Alam, 1989). Deltaic sedimentation during the Miocene has been documented based on extensive studies of lithofacies (e.g., Alam, 1989; Uddin and Lundberg, 1999), and fossil assemblages (mostly palynology; as cited in Reimann, 1993), confirmed by studies of seismic reflection character (Salt et al., 1986; Lindsay et al., 1991). Many investigations of litho
facies have reported mainly coastal to shallow water deposits, with some reports of deep marine strata in SE Bangladesh (e.g. Reimann, 1993; Gani and Alam, 1999). Tests of foraminifers and hystrichospherids from the more shaly sequences in the Chittagong Hills also indicate brackish to marine environments. Remains of gastropods, lamellibranchs, echinoids and burrows discovered in cross-bedded sandstone of the Bhuban Formation indicate near shore depositional environments. Remains of gastropods, lamellibranchs, echinoids and burrows discovered in cross-bedded sandstone of the Bhuban Formation indicate near shore depositional environments (Reimann, 1993). A paleogeographic reconstruction of the Bengal basin in the Miocene (Alam, 1989) shows several deltaic complexes prograding from the northeast, east, west and north-west in to the basin. Strata of the overlying Tipam Formation were laid down under continental fluviatile conditions (Alam, 1989).

During this time, strata along the eastern margin of the Bengal basin began to be actively deformed, producing a distinct mobile belt (folded flank of the deeper part of the basin) known as the Chittagong folded belt. The Late Miocene–Pliocene time was a period of intense deformation and uplift in the mobile belts of the Bengal basin, contributing to wide spread regression of the sea (Hoque, 1974). A regression during the Late Miocene (the Messinian) has also been seen in seismic reflections recorded far off shore in the Bay of Bengal (Curray and Moore, 1971). West directed compression propagated westward, deforming strata in the area of the Chittagong Hiltracts. Deposition of fluviatile and deltaic sandstones and conglomerates (Dupi Tila Sandstone and Dihing Formation) took place in the eastern fold belt and in the Sylhet trough (Holtrop and Keizer, 1970).

The Quaternary in the Bengal basin was marked by a general regression presumably due to voluminous sediment influx from the highlands, although glacioeustatic oscillations have also been recorded (Morgan and McIntire, 1959). Much of the present geomorphic landscape of the Bengal basin and the regions surrounding it developed during this time (Hoque, 1974). Pleistocene and Holocene deposits are represented on land by three areas of red clay deposits, a coastal coral bed and several small sand bodies, but voluminous deltaic deposits of this age are restricted to the offshore regions of the Bay of Bengal.

2.7 STRATIGRAPHIC FRAMEWORK OF BENGAL BASIN

The earliest stratigraphic account in the study area appears in Evans (1932) who established a lithostratigraphic classification for the Tertiary strata exposed in the
Lower Assam Basin (Table 2.1). Since then in various published and unpublished reports, without any detailed regional correlation, this early stratigraphy has served as

Fig. 2.4. Stratigraphic frame work of the Bengal basin. Miocene sediment thickness is much lower near the Indian platform in the north-western part of the basin. This shelf area of the basin is floored by continental crust (after Khan and Muminullah, 1980; Uddin and Lundberg, 1999; and many other sources).

the basis for stratigraphic correlation of the sediments within the entire Bengal Basin. Later, studies based on micropaleontology (e.g. Banerji, 1984), palynology (e.g. Baksi, 1972; Reimann, 1993), and seismic stratigraphy (e.g. Salt et al., 1986; Lindsay et al., 1991) have partly refined this early scheme. The oldest sedimentary sequence
exposed along the Indo–Burman collision zone is the Late Cretaceous–Eocene sediments known as the Disang Group (Rao, 1983), which occurs in a linear belt within the Naga–Chin–Arakan Hills. The lithological association, faunal content, and other evidences from the Lower Disang sediments suggest that these were deposited in deep water (trench and/or floor) setting and also on the slope as turbidites (Roy, 1983). On the other hand, the Upper Disang sediments, thought to be equivalent to the Sylhet Limestone Formation of the stable shelf, were deposited in shallow water conditions in an actively subsiding basin (Rao, 1983). The Sylhet Limestone is overlain by a thin (40–90 m thick) argillaceous unit, the Upper Eocene Kopili Shale Formation, in which the lithological and fossil contents indicate paralic (brackish-marshy) depositional environments (Uddin and Ahmed, 1989; Reimann, 1993).

2.7.1 Barail Group

The Barail Group (Table 2.1), consisting mainly of pale-gray, fine to very fine-grained, carbonaceous sandstone, with minor siltstone and silty shale, is thought to have been deposited during a major regression that exposed most of the Indian platform part of the Bengal Basin. Lithologically similar and palynofacies equivalent rocks of Oligocene age (Reimann, 1993) are exposed along the northern fringe of the Sylhet Trough immediately south of the Dauki Fault (Alam, 1991; Johnson and Alam, 1991). These rocks have been interpreted as deposits of mainly tide dominated shelf environments (Alam, 1991). The Barail rock in general comprises dominantly pale-gray, very fine to fine grained carbonaceous sandstone with minor siltstone and silty shale interbeds.

The geosynclinal facies of Barail Group are subdivided into Laisong, Jenam and Renji Formations. In Assam, Barail Group are exposed along two different strips, in the south-eastern part of North Cachar Hills, i.e. to the South of Haflong–Disang. In Meghalaya the Barail Group are mainly exposed in the Garo Hills and consists of about 1000 m thick sandstone with minor shale and carbonaceous shale/coal sequence. In Nagaland thin sequence of sediments of Barail Group resting unconformably on a pre-Tertiary granitic basement exposed mainly in Dhansiri valley. In Assam Shelf part of Nagaland Barail sediments are thrusted over by tectonic slices of Schuppen Belt. In Manipur, Barail Groups are restricted to the western and southwestern parts. In Arunachal Pradesh, Barail Group is usually succeeded by the Tipam Group with an
apparent erosional unconformity in the Schuppen-belt. It is well developed in Namchik-Namphuk, Makum, Dilli-Jeypore and Borjan coal-fields.

![North-South and East-West crustal cross sections through the Bengal Basin](image)

**Fig. 2.5 (a-b).** North–South and East–West crustal cross sections through the Bengal Basin (modified from Murphy and Staff of BOGMC, 1988; BOGMC, 1997).

### 2.7.2 Surma Group

Overlying the Barail Group is the Surma Group rocks, which are widely exposed in the surface and also encountered in all the wells in eastern Bangladesh. The lower to middle Miocene Surma Group, comprising the Bhuban and Bokabil Formations, has been deposited during repeated transgressions and regressions. The group consists of dark gray shale, siltstone, fine to coarse-grained sandstone, and occasional intraformational conglomerate, and attains a thickness of more than 4 km
in the Mizoram area. In the Evans’ (1932) lithostratigraphic scheme, the basis for subdivision

**Table 2.1. Stratigraphic succession of the Sylhet Trough in the north-eastern part of the Bengal basin (revised from Hiller and Elahi, 1988)**

<table>
<thead>
<tr>
<th>Age (approx.)</th>
<th>Group</th>
<th>Formation</th>
<th>Seismic Marker</th>
<th>Thickness (max) (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holocene</td>
<td>Alluvium</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pleistocene</td>
<td>Dihing</td>
<td>Upper Dupi Tila</td>
<td>Yellow</td>
<td>3350</td>
</tr>
<tr>
<td></td>
<td>Dupi Tila</td>
<td>Lower Dupi Tila</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Late Pliocene</td>
<td>Tipam</td>
<td>Girujan Clay</td>
<td>Brown</td>
<td>3500</td>
</tr>
<tr>
<td></td>
<td>Surma</td>
<td>Tipam Sandstone</td>
<td>Red</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Upper Marine Shale</td>
<td>Violet</td>
<td>3900</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lower Undifferentiated</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Early Pliocene</td>
<td>Surma</td>
<td></td>
<td>Blue</td>
<td>7200</td>
</tr>
<tr>
<td>Oligocene</td>
<td>Barail</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paleocene-</td>
<td>Jaintia</td>
<td>Kopili Shale</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eocene</td>
<td></td>
<td>Sylhet Limestone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-Paleocene</td>
<td></td>
<td>Undifferentiated sedimentary rocks</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(with some volcanic?) on the</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>continental basement complex</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

of the Bhuban and Bokabil Formations is the relative proportion of the argillaceous or arenaceous beds. Thus, the Middle Bokabil Member represents a sandier unit within the dominantly argillaceous Bokabil Formation, whereas the Middle Bhuban Member is more argillaceous division of the dominantly arenaceous Bhuban Formation. These descriptions of the broad subdivisions of the Bhuban and Bokabil Formations are difficult to correlate with the lithology of the Surma Group penetrated in the subsurface as well as exposed succession of the EFB, where most part of the Bhuban
Formation is dominantly argillaceous. The upper part of the Bokabil Formation is pelitic, and is traditionally known as the ‘Upper Marine Shale’ (Holtrop and Keizer, 1970), which represents the last marine transgression over the Sylhet Trough in northeastern part of the Bengal Basin (Table 2.1).

2.7.3 Tipam Group

The Surma Group is unconformably overlain by the upper Mio–Pliocene Tipam Group, which is divided into the Tipam Sandstone and Girujan Clay Formations. The Tipam Sandstone typically consists of yellowish brown to reddish brown, coarse-grained, cross-bedded to ripple-laminated sandstone with minor siltstone and mudstone and interpreted as deposits of bed load-dominated low-sinuosity braided-fluvial systems (Johnson and Alam, 1991; Alam and Ferdous, 1995). The Girujan Clay, composed of brown, blue and gray mottled clay, is interpreted as lacustrine and fluvial overbank deposits (Reimann, 1993). The Plio–Pleistocene Dupi Tila Sandstone, unconformably overlying the Tipam Group, comprises a sandy lower unit and an argillaceous upper unit (Hiller and Elahi, 1988). The fining-upward sequences characteristic of the Dupi Tila Sandstone, with alternating channel-fill and floodplain deposits, has been interpreted as deposits of high-sinuosity meandering river systems (Johnson and Alam, 1991). The younger Pleistocene deposits, those occur locally as relatively thin unit unconformably overly the Dupi Tila Sandstone.