2.1 REGIONAL GEOLOGICAL SETUP

Understanding the tectonic setting of a region is a necessary pre-requisite to understand the paleogeographic and sedimentation patterns of that region. Further better understanding of these aspects in a sedimentary terrain is essentially depend-ent upon understanding the stratigraphy with chronologic controls. The regional geo-
logical setup of the study area is formed by the 2500 long, 300 km wide east-west Himalaya and the 1500 km long 230 km wide north-south belt of the Indo-Burman ranges formed as India collided with Eurasia and the Burmese platelet (See fig. 2.1). The Himalayan belt is made up of four longitudinal lithotectonic units, juxtaposed along generally north-dipping thrust faults (Fig. 2.2). The lithologic and tectonic characteristics of these belts remain constant over long distances along strike (Gansser, 1964). From south to north, these units are (1) the Sub-Himalaya, representing the Miocene to Pleistocene molasse deposits of the Siwaliks, separated from the Indo-Gangetic Plain by the Himalayan/Main Frontal thrust; (2) the Lower, or Lesser, Himalaya, which represent southward-directed thrusts and nappes composed of Precambrian and Paleozoic sedimentary rocks, crystalline rocks, and granites; (3) the Higher Himalaya, located north of the Main Central thrust, composed of schists, gneisses, and granites, and located across the Indus-Tsangpo suture; and (4) the Tethys Himalaya and Trans- Himalaya, representing fossiliferous Cambrian to Eocene sedimentary rocks (shallow-water deposits, such as limestone, calcareous sandstone, and dolomite), batholiths, and volcanic rocks. The suture between India and Asia is marked by ophiolitic rocks, and is located south of the Trans- Himalaya and locally adjacent to the Precambrian Central Gneiss of the Higher Himalayas (Jain and Kanwar, 1970).

The Indo-Burman ranges are made up mainly of Cretaceous to Eocene pelagic strata overlain by thick Eocene to Oligocene turbidites and upper Miocene to
Fig. 2.1: Index map of Bangladesh and adjoining areas in the eastern part of the Indian subcontinent. This map shows location of the exploratory wells, lines of geological cross-sections shown in figures and also the major tectonic features surround-
Pleistocene molasses (Ni et al., 1989). Several authors (e.g., Fitch, 1970; Ni et al., 1989; Mitchell, 1993) have suggested that the Indo-Burman ranges are trench deposits containing ophiolite melanges scraped off the subducting Indian plate. East-west crustal compression is still active in the Indo-Burman ranges, as evidenced by north-trending folds of Pliocene–Pleistocene strata (Le Dain et al., 1984). Studies of focal mechanisms suggest that the basement of the Indian plate below the Indo-Burman ranges is moving north with respect to the rest of Asia (Ni et al., 1989; Chen and Molnar, 1990), producing right-lateral slip along the Sagaing and other faults located east of these ranges (Fig. 2.3; Le Dain et al., 1984). The collisional history of the Himalayan mountain chain, developed along a region once occupied by the west-northwest–south-southeast Tethys ocean, is recorded in sediments deposited in subsiding foreland basins to the south (Burbank et al., 1996), including the Bengal basin of Bangladesh (Fig. 2.4). This basin is predominantly a huge delta complex, covering about 144 000 km$^2$ onshore and 63 000 km$^2$ offshore, and contains as much as 16 km of synorogenic Cenozoic sequences derived from the eastern Himalayas and the Indo-Burman ranges (Uddin and Lundberg, 1998).

The timing of initial collision of the Indian plate with Eurasia has been debated (Cochran, 1990; Butler, 1998). Suggestions range from the Cretaceous-Tertiary boundary, on the basis of paleomagnetic work (Klootwijk et al., 1992), to various times in the Eocene (Rowley, 1996). An early Eocene collision between Asia and sedimentary rocks of the leading edge of India (a soft collision) at about the time of magnetic anomaly 22 at 53 Ma is suggested on the basis of a 50 per cent decrease in spreading rates in the central Indian Ocean (Sclater and Fisher, 1974). A middle Eocene date is based on the similarity of mammalian fossils between India and Mongolia (Sahni and Kumar, 1974), and on paleomagnetic data and plate motions (Dewey et al., 1988). A late Eocene collision has been proposed on the basis of radiometric dating of plutonic rocks of the Trans-(Tethys) Himalaya, inferred to represent the end of subduction of oceanic crust at the leading edge of India (Honegger et al., 1982; Petterson and Windley, 1985). Beck et al. (1995) suggested, on stratigraphic grounds, that initial collision occurred between 66 and 55.5 Ma and there is firm evidence of collision by 49 Ma (early–middle Eocene time). This is considerably earlier than the middle Miocene age, originally postulated by Gansser (1964), for
Fig. 2.2: Regional map showing the present day Ganges delta and Bengal shelf with the major rivers supplying sediment to the delta from the largest mountain range in the world (after Alam et al., 2003).
Fig. 2.3: Regional tectonic map of Bangladesh, with the position of the Bengal basin, Chittagong–Tripura Fold Belt (CTFB) and the Indo-Burmesse ranges (IBR) highlighted. The modern Ganges delta occupies a large proportion of the basin. SF—Sagaing fault, KF—Kabaw fault, MBT—Main boundary thrust, DF—Dauki fault. (Modified after Curay et al., 1982; Maung, 1987; Ni et al., 1989.)
initial uplift of the Himalaya. The collision between India and Eurasia did not take place simultaneously along the entire Himalayan belt (Dewey et al., 1989). From 45 Ma to the present, India has rotated 33° counter clockwise, the motion relative to Asia having changed from predominantly northeast to more northerly, accompanied by a 50 per cent reduction in velocity. Most geological information constraining the timing of collision has been produced from the western portion of the system. The stratigraphic record of the collision has been studied in some detail in the western Himalaya, beginning with the classic study of Krynine (1937); relatively few hard data on collisional timing have been reported from the eastern Himalayan foreland basin.

Distal eastern equivalents of the Siwalik sequences have been studied in the Bengal fan and in seismic surveys (Curray, 1991) on drilling legs (Ingersoll and Suczek, 1979; Cochran, 1990; Amano and Taira, 1992). Drilling has recovered strata as old as about 18 Ma, and detrital geochronology and isotopic studies of these strata indicate that orogenesis had begun prior to this time (e.g., Copeland and Harrison, 1990; France-Lanord et al., 1993, 1994). The Bengal basin, the land pathway that links the Himalaya to the Bengal fan, is a modern collisional foreland basin that contains both pre-tectonic and syntectonic stratigraphic sequences. Because of its location between the eastern Himalaya and the Indo-Burman ranges, Bengal basin sequences contain detrital sediments that yield information potentially relating to the uplift and unroofing history of both orogens. However, few detailed provenance studies have been carried out on the sediments of the Bengal basin.

2.2. THE BENGAL BASIN

Oblique collision of the Indian and Burmese plates during the Eocene–Oligocene (Curray et al., 1982) resulted in obduction of the accretionary prism, forming the Indo-Burmese ranges (IBR). With continued subduction of the Indian plate, sediments within the Bengal basin have been compressed and uplifted to form the Chittagong–Tripura Fold Belt (CTFB), west of the Indo-Burman ranges (Fig. 2.5). Sediments into the Bengal basin are considered to have been supplied initially from two sources, an easterly source (the palaeo-Brahmaputra river), as well as a more westerly source (the palaeo-Ganges river; Banerji, 1984; Uddin and Lundberg, 1999).
The Bengal basin has two broad divisions: (1) the “Indian platform” (also known as the “stable shelf” area) to the northwest and west, and (2) the area known as the “Bengal foredeep,” a region of much thicker sediment accumulation (Fig. 2.5). The Bengal foredeep includes the Sylhet trough (also known as the Surma basin) in the northeastern Bengal basin and the Chittagong Hill Tracts in eastern Bangladesh, which contain some of the best studied sequences of the Bengal basin. The present
sediment fill of the Bengal basin is asymmetric, the greatest thicknesses being near its northern and eastern margins. Seismic-reflection studies (Curray, 1991) show that sedimentary and meta-sedimentary rocks beneath the Bangladesh continental shelf are at least 22 km thick; 16 km are inferred to be collisional deposits that overlie 6 km of pre-collisional strata interpreted as buried continental rise and pelagic deposits.

2.3 GEOLOGICAL ELEMENTS AND TECTONIC FRAMEWORK OF NE HIMALAYA AND INDO-BURMESE RANGE (IBR)

2.3.1 The Himalayan belt

The Himalayan Range which comprises in age from Proterozoic to Holocene have been subdivided into three NE-SW trending zones coinciding with three geomorphic divisions viz, the Higher and Tethys Himalays, the lesser Himalaya and sub- Himalaya, by two major tectonic planes, the Main Central Thrust (MCT) and the Main Boundary Fault (MBF).

2.3.2 Shillong Plateau

The Shillong Plateau (SP) in the northeast India region is a part of the Indian shield that is separated out from the peninsular shield and moved to the east by about 300 km along the Dauki fault. The gigantic E-W trending Dauki fault separates the SP to the north and the Bengal basin to the south. The mighty Brahmaputra river, on the other hand, separates the SP from the Himalaya to the north. The E–W segment of the river at the northern boundary of the SP is named Brahmaputra fault (Nandy, 2001). The Mikir massif, a part of the Shillong massif, moved to the northeast; the nearly 300–400 km long NW–SE trending Kopili lineament separates them (Nandy, 2001). The long Kopili lineament is named Kopili fault, and it extends into the Himalaya (Kayal 2001, Bhattacharya et al., 2002).

The northeast India region is one of the most seismically active zones in the world; the region is jawed between the two arcs, the Himalayan arc to the north and the Indo- Burmese arc to the east (Kayal et al., 2006). The region bounded by latitude 22–29°N and longitude 90–98°E, produced two great earthquakes ($M > 8.0$) and
about 20 large earthquakes (8.0 > M > 7.0) since 1897. The Shillong plateau was the source area for the 1897 great earthquake M 8.7, and the Assam syntaxis was the zone for the 1950 great earthquake M 8.7. Several large earthquakes occurred along the Indo-Burma ranges in the recent and historic times. Oldham (1899) postulated that a north-dipping thrust fault at the southern boundary of the SP had been the possible source for the 1897 great earthquake. Seeber and Armbruster (1981) supported this model. Kayal and De (1991) studied temporary analog microearthquake network data in the SP region and inferred that the north dipping Dapsi thrust is seismically active and possibly produced the 1897 great earthquake. They identified that the seismically active Dapsi thrust is a western extension of the Dauki fault; the Dapsi thrust separates the Archaean gneiss and the Tertiary sediments within the SP region. The Dapsi thrust not only truncates the seismic activity to its south, it also truncated the highest intensity isoseismal of the 1897 great earthquake (Kayal and De, 1991). Bilham and England (2001), based on geodetic and GPS data, proposed a ‘pop-up’ tectonic model of the SP, and argued that the 1897 great earthquake was produced by a south dipping hidden fault at the northern boundary of the SP; they named it the ‘Oldham fault’ that extends from a depth of about 9 km down to 45 km. They further suggested that the SP earthquakes are caused by the ‘pop-up’ tectonics between the Dauki fault and the Oldham fault. Evans (1964) and Nandy (2001), on the other hand, argued that the Dauki fault is a near vertical or a south dipping strike-slip/ normal fault, not a north dipping thrust fault. Recently Rajendran et al. (2004), based on geological and geophysical data, also argued that geologically no surface evidence of the Oldham fault exists; the south dipping structure is, however, conformable with the E–W segment of the Brahmaputra fault (river) at the northern boundary of the SP. The surface projection of the Oldham fault and the surface trace of the Brahmaputra fault are, very close within 20 km at the 1897 great earthquake epicentre zone (Kayal et al., 2006).

2.3.3 Mikir Hills

The exposure limit of the Indian Peninsular Shield rocks towards east is marked by the Garo-Rajmahal gap. Rocks comprising the Shillong Plateau and Mikir Hills represent the re-emergence of shield elements on the east of the gap. The highland generated by these shield rocks occupies a crucial position between the Hima-
laya and the Indo-Burmese Range. The plateau is dominated by high grade Archean Gneissic Complex, overlain by Proterozoic intracratonic sediments of Shillong Group with metavolcanic Khasi Greenstone, both intruded by Upper Proterozoic-early Palaeozoic granites. Jurassic-Cretaceous volcanisms represented by the Sylhet Trap occur along the southern margin of the plateau and intimately associated with the E-W Dauki fault system. Cretaceous-Eocene stable shelf sediments cover the southern and eastern periphery of the plateau and southern fringe of the Mikir Hills which towards east, are juxtaposed with sediments of the trench facies of Indo-Myanmar mobile belt. Almost uninterrupted intra-continental sedimentation continued along the southern margin of the plateau till Quaternary period. The occurrences of Upper Cretaceous carbonatite-ultramafic complex along a NE fracture zone in the east central part of the plateau and in Mikir Hills is noteworthy. N-S to NW-SW trending active faults/fractures predominate in this domain.

2.3.4 Mishmi Hills

The area lying to the east of the orographic bend in the eastern most part of the Himalaya bordering China exposes a thick sequence of meta-sediments and associated granite gneiss, granodiorite, and granites with mafic and ultramafic intrusive which are collectively referred to as the Lohit Complex. It has a regional NW-SE trend, abutting against the Himalaya along the Tidding Suture in south east and in south, against the NE – SW trending Naga Patkoi ranges along Mishmi Thrust. There is a difference of opinion about the northern continuation of Mishmi Thrust. According to Gopendra Kumar (1997) the Mishmi Thrust takes a swing to west and does not extend north westwards. G.S.I. map, on the other hand, shows it as a continuously extending north-westward which has been found by Gopendra Kumar as Roing fault/thrust.

2.3.5 Tidding Suture

It is NW-SE trending tectonic lineament considered to mark the plate boundary between the Indian and Central Burmese plates. The tectonic plate dips steeply towards east. It has been continuously traced from Dhapa Bum in the south-
ern part of the Lohit Valley to beyond south of Tuting in Siang Valley in the north-west at the south-east end.

2.3.6 Lohit Thrust

It runs parallel to the Tidding Suture demarcating the tectonic contact between the Tidding and the Mishmi Formations, systematic geological mapping of the area reveals that the crystallines viz. dioritic gneiss and granodiorite are intrusive into metamorphities viz. Hornblende schist, Kyanite-sillimanite–biotite gneiss and marbles which is clearly evidenced by the presence of the latter within the crystallines as bands, lenses and rafts. Nandy et al. (1975) who worked previously in this area considered crystallines to be older to metamorphites and also felt that these crystallines have overridden the parametamorphites to the southwest along a thrust, which they called it as Lohit Thrust.

2.3.7 Naga Patkoi Ranges

Naga-Patkoi ranges abut against Mishmi hills along Mishmi Thrust and form a part of late Mesozoic Neogene Arakan Basin. This segment of Arunachal Pradesh is considered to be the part of the pre-Cambrian shield.

2.3.8 Assam Shelf

During the Palaeogene period the present Assam Valley region was platform shelf of the Indo-Myanmar mobile belt. It was transformed into intermontane continental basin during the Neogene time after the upliftment of the Barail range. However, the eastern margin of the Assam shelf assumed the character of a foredeep for the deposition of the Neogene molasse (Raju, 1968) along the NE linear belt west of the rising Indo-Myanmar mobile belt. The regional hidden basement ridge which runs along the present course of the Brahmaputra river from the Mikir Hills plunges northeast to pass through Moran and Tengakhat area. The basement surface forms a major high near the Tenughat-Bordubi belt whose flank are dipping northwest and southeast, popularly known as the ‘Brahmaputra Arch’.
On the basis of surface and subsurface information provided by oil drilling
and geophysical surveys, the stratigraphy of the Assam shelf and molasse basin as
established by the oil geologists may be summarised as follows:

In the shelf area the Lower Gondwana Formation (Permian) was encoun-
tered in one well at Barpathar in Upper Assam (Naik et al., 1993). However, the Pre-
cambrian granitic basement is overlain locally by Upper Cretaceous Langpar Forma-
tion (Handique and Mallick 1990). This is followed upward by the Palaeocene-
Eocene formations of Jaintia Group consisting of the Theria Formation of sandstone,
calcareous sandstone and limestone (60-170 m); Sylhet Limestone Formation of
splintery shale with sandstone and limestone (350-450 m) and by the Kopili Forma-
tion comprising alternations of shale, sand and coal bands (280-500 m). The Oligo-
cene, representing shallow marine, lagoonal and fluviatile environments of unstable
conditions, contains 500-1200 m thick sequence of mudstone, shale, sandstone and
coal seams of the Barail Group. At the close of the Oligocene, there had been a
marked hiatus, and then molasse type sediments of the doubtful Surmas and Tipams
were deposited with a pronounced unconformity during the Miocene in an unstable
basin along the eastern edge of the platform/shelf. The Tipam Group is represented
by the lower arenaceous facies of Sandstone Formation (500-900 m) and upper argil-
laceous Girujan Clay Formation (100-2300 m), while the platform/shelf area was
covered only by the arenaceous facies of the Tipam Group. The Tipam are overlain
by the Pliocene Dupi Tila/Namsang and the alluvium, occurs a thick formation of
Dihing/Dekiajuli beds of 1300-2000 m thickness of unconsolidated sand with clays
and boulder beds of Pleistocene age.

The Palaeogene sediments show an increase in the thickness from northeast
to southwest indicating deeper basinal condition towards southwest. The environ-
ment of deposition of these sediments changed from marine to lagoonal and then to
deltaic and finally to fluviatile through time. The Neogene to Recent sediments are
mostly molassic in nature and were deposited extensively in fluviatile environment
with pulses of the brackish to deltaic conditions. The thickness of these Neogene
sediments show shift in depocentre towards north and northeast in the Tirap district
of Arunachal Pradesh during Plio-Pleistocene time.
2.3.9 Central Myanmar Basin

With onshore length of about 1100 km, the Central Myanmar basin extends from the Gulf of Martaban towards NNW to N, and then to NNE to as far as the Hukuang basin in north Myanmar. In south Chindwin-Shwebo basin, it attains its largest E-W extension of about 200 km. To the extreme south and south east of the basin can be continuously traced for about 3000 km in the Andaman sea, and as far as the south Sumatra Tertiary basin (Bender, 1983). In the Myanmar area it is bounded in the west by the Indo Myanmar mobile belt, in the east by the Sino-Myanmar ranges and in the north by the Mishmi block. The basin contains sediment from Cretaceous to Recent, the older rock being well developed along the western margin.

Tectonically the basin can be divided into the western ‘Forearc Trough’ and the eastern faulted ‘Backarc Basin’ which are separated by the arcuate ‘Magmatic Arc’ that extend from the Jade Mines in north Myanmar to Narcondam-Barren islands in Andaman sea through Monywa, Mt. Popa and Irrawaddy Delta. This intrabasinal arc continues to the continental margin arc in North Sumatra.

2.3.10 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., 1993), 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.

2.3.1 Brahmaputra Plain

During the Himalayan Orogeny and simultaneous with the developments of sub-Himalaya and Arakan Yoma mountains in early middle Pleistocene, a depression was formed in between the rising mountains. This valley or basin, referred as Brahmaputra valley, was filled up by fluvial lacustrine sediments during the later part of the Quaternary period and evolved as a plain – The Brahmaputra plain. They are made up of post-Siwalik Quaternary sediments and the basements of pre-Cambrian rock or the floor of Palaeogene – Neogene sediments.

2.4 STRATIGRAPHIC FRAMEWORK

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 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 (Fig. 2.3). 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).

2.4.1 Barail

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 comprise dominantly pale-gray, very fine to fine grained carbonaceous sandstone with minor siltstone and silty shale interbeds.

Fig 2.5: North–south and east–west crustal cross sections through the Bengal Basin (modified after Murphy and Staff of BOGMC, 1988; BOGMC, 1997).
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.

**Table 2.1:** Stratigraphic succession of the Sylhet Trough in the northeastern 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>Pleistocene</td>
<td>Dihing</td>
<td>Dihing</td>
<td>Yellow</td>
<td>3350</td>
</tr>
<tr>
<td></td>
<td>Dihing</td>
<td>Upper Dihing</td>
<td></td>
<td>3500</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lower Dihing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Late Pliocene</td>
<td>Tipam</td>
<td>Grijans Clay Tipam Sandstone</td>
<td>Brown</td>
<td>3900</td>
</tr>
<tr>
<td>Mid-Pliocene</td>
<td>Surma</td>
<td>Upper Surma</td>
<td>Red</td>
<td>3500</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lower Surma</td>
<td>Violet</td>
<td></td>
</tr>
<tr>
<td>Early Pliocene</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Miocene</td>
<td>Barail</td>
<td>Undifferentiated</td>
<td>Blue</td>
<td>7200</td>
</tr>
<tr>
<td>Oligocene</td>
<td>Jaintia</td>
<td>Kopili Shale</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paleocene-Eocene</td>
<td></td>
<td>Sylhet Limestone</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tura Sandstone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-Paleocene</td>
<td></td>
<td>Undifferentiated sedimentary rocks (with some volcanics?) on the continental basement complex</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 2.4.2 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 attain a thickness of more than 4 km in the Mizoram area. In the Evan’s (1932) lithostratigraphic scheme, the basis for subdivision of the Bhuban and Bokabil Formations is the relative proportion of the argillaceous or arenaceous beds. Thus, the Middle Bokabil Member represents a sandy 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).

2.4.3 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, that occur locally as relatively thin unit unconformably overlying the Dupi Tila Sandstone.

2.4.4 Assam Shelf and Arunachal Pradesh

The pre-Tertiary stratigraphy of the Bengal basin is known only from the northwest part of the basin. An ~1 km thick Permo–Carboniferous Gondwana bitu-
minous coal, inferred to have formed in intracratonic, fault-bounded basins, overlies Precambrian basement, and is overlain by about 500 m of the Cretaceous basaltic Rajmahal–Sylhet Trap (equivalent to the Deccan Traps). Shallow-marine strata of the Paleocene to lower Eocene Cherra (or Tura) Formation consist mostly of clastic rocks and some carbonaceous material and impure limestones. Marine transgression followed deposition of this unit, leading to deposition of the widespread middle Eocene nummulitic Sylhet Limestone. This limestone reaches a thickness of about 250 m in the Bengal basin, and is interbedded with sandstone, some of which is exposed in the Sylhet trough. The Sylhet Limestone is overlain by the 40–90-m-thick upper Eocene Kopili Formation, which consists mostly of argillaceous and fossiliferous materials, and represents a paralic transitional stratigraphic unit between middle Eocene carbonate facies and mainly arenaceous Oligocene sequences. The Oligocene Barail Formation was deposited during a marine regression. The 800–1600 m Barail Formation is composed of dominantly massive to thickly bedded sandstone interpreted by Banerji (1984) as estuarine and deltaic deposits. These upper Eocene and Oligocene strata are exposed in the Sylhet trough. The Miocene Surma Group, consisting of the Bhuban and Boka Bil Formations, was deposited during repeated transgressions and regressions. This unit is well developed in the eastern fold belts and deeper parts of the basin, and is about 4.5 km thick in the northern Chittagong Hill Tracts and in the Sylhet trough (Fig. 2.5). In the northwestern stable shelf area, the Surma Group is represented by the much thinner (150 m to 1.3 km) Jamalganj Formation (Khan and Muminullah, 1980). The Bhuban Formation is composed mainly of sandstone, siltstone, shaly sandstone, and mudstone; the Boka Bil Formation is generally composed of shale, siltstone, and sandstone. A shaly upper member of the Boka Bil Formation was designated by Holtrop and Keizer (1970) as the “Upper Marine Shales,” representing the last Miocene transgression.

The Surma Group is unconformably overlain by the upper Miocene to Pliocene Tipam Group, consisting of the Tipam Sandstone Formation and Girujan Clay Formation. The Tipam Sandstone Formation, which is locally as thick as 2.5 km, is composed mostly of weathered, medium- to coarse-grained, cross bedded massive sandstone, and has been interpreted to have been deposited in bedload-dominated braided-fluvial environments (Johnson and Alam, 1991). The Girujan Clay is locally
as thick as 1 km, and is composed dominantly of mottled clay deposited in lacustrine, flood-plain, and overbank environments (Khan and Muminullah, 1980). These units are overlain unconformably by the Pliocene–Pleistocene Dupi Tila Formation, comprising mostly massive trough–cross-bedded coarse to pebbly sandstone, which reaches a maximum thickness of at least 2.3 km in the Sylhet trough. The Dupi Tila Formation contains alternating channel and flood-plain deposits, and has been interpreted as a meandering-river deposit (Johnson and Alam, 1991).

### 2.4.5 Siang Group

It comprises medium to high grade metamorphic rocks, like garnetiferous graphite schist, staurolite-garnet-grahitic schist, calc-silicate rocks, staurolite-garnet-biotite schists, biotite gneisses etc. At Angguing, the graphitic schists are characterized by the idiomorphs of staurolite prisms. Near Yamelling (Singa), the white marble bands are present in association with graphite schists.

### 2.4.6 Siyom Group

In the Siyom valley areas, the Siyom Group is represented by biotite schists, schistose quartzite, amphibolite, gneisses, migmatites, schistose quartzites, with phyllite, black slates and limestone. The same litho-assemblage has also been recognized in the Subansiri region, where the gneisses, migmatites etc. are known as Ziro gneisses, Daporijo gneisses etc. The metavolcanics exposed at Tuting succeed the Siang Group with an extrusive contact, the contact being marked by a garnetiferous zone of about 10-15 cm in thickness. It is ascribable to the effects of thermal metamorphism. These metavolcanics are not traceable beyond Sirup Chu and are cut off by the thrust plane which is responsible for bringing Tuting granites and gneisses against the rocks of Siang Group.

### 2.4.7 Lower Gondwana Group

These rocks are characterized by the carbonaceous phyllite with coaly lenses, grey sandstone, black slates with calcareous nodules as observed at Ganu, Gensi, Tatamori, Daring and Rylu areas. Along Pasighat-Rotung road section the contact between Gondwana and Miri may be of transitional nature. Local shearing
along the contact has also been noticed. Near Pasighat, the nummulite bearing arenaceous limestone is exposed. Its extent and true nature of disposition is little known.

### 2.4.8 Yingkiong Formation

The rocks of this formation occupy a large tract of land between Yamne and Siang valleys. They are composed of thick succession of light grey sandstone, siltstone, purple and pale green shale, black shale, and volcanic sediments. Earlier this succession was considered to be of Pre-Cambrian age. Recent investigation indicates that the Yingkiong Formation is of Lower Eocene age, for it is intimately associated with nummulitic limestone bands. Discovery of Eocene fossils from the Yingkiong Formation has necessitated revision with regard to the age of the Abor Volcanics.

### 2.4.9 Siwaliks

The Sub-Himalayan zone is occupied by the Siwalik belt. The Siwalik is divided into Lower, Middle and Upper. The Lower Siwalik is composed of hard brownish grey sandstone with clay intercalations. The massive medium to coarse grained sandstone is the dominant lithology of the Middle Siwalik. The Upper Siwalik includes silty-clays, sands, pebble, and boulder beds. The Siwalik belt is separated from the Miri quartzite and Gondwana by a system of steep faults, commonly known as Main Boundary Fault.