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Research Papers

Lithostratigraphy of the Paleogene Shelf Sediments in Assam and Meghalaya – A Review

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ABSTRACT

The Paleogene Shelf sediment are well developed in Garo hills, Khasi and Jiantia hills along the southern margins of Shillong Plateau in Meghalaya, parts of Mikir and North Cachar hills of Assam and also in the subcrops of Dhansiri and Upper Assam valleys. These sediments represent diverse depositional environments from marine, lagoonal, tidal flat to fluvio–deltaic exhibiting the effects of differential tectonic movements in basin floors,changes in shorelines, sediment source and varying degree of energy conditions of thetransporting media. As a consequence, certain problems may be encountered in erecting a unified scheme of generalized stratigraphic columns for the entire region under review. The stratigraphic study of these lithounits would obviously help to understand the diverse and subtle variations in lithofacies of the Paleogene sequence in different areas of basin positions.

A synthesis of all the available and relevant geoscientific data shows that some controversies and doubts still exist in the various schemes of Stratigraphic classifications and probable correlations advocated by different workers from time to time. An attempt has been made in this paper to discuss some of these confusions in the course of reviewing the stratigraphic status and terminology particularly of Langpar, Basal Sandstone Formations, Jaintia and Barail Groups of Paleogene shelf sediments in Assam and Meghalaya with reference to Indian Standard Stratigraphic codes and norms. To avoid further confusion regarding the usage of different stratigraphic nomenclature for the litho-units of the Paleogene shelf sediments, a unified lithostratigraphic scheme has been put forward for regional stratigraphic analysis.

KEYWORDS : Lithostratigraphy, nomenclature, classification, Paleogene shelf sediments, Assam and Meghalaya.

INTRODUCTION

The shelf sediments developed in the southern fringe of Shillong Plateau in Meghalaya, in parts of North Cachar – Mikir Hills and beneath the thick alluvium cover of Dhansiri and Upper Assam valleys represent a classic and complete section of Cainozoic sequence as most of the lithotypes of different tratigraphic horizons are well preserved. The shelf facies deposited during the Paleogene on the stable part of the platform in fact is an extension of the shelf facies of Bengal Basin. In Assam, shelf facies sequence attained nearly 7000m. of sediments and occurs under the alluvium, while about 6400m. thick Upper Cretaceous-Cainozoic out crops fringing the southern part of Shillong Plateau and detached North Cachar-Mikir Hills.

Systematic exploration activities by the geological survey organizations and oil companies in

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the shelf areas of Assam and Meghalaya for petroleum and coal resources have generated valuable surface and subsurface information over the decades. Our present knowledge of the geology, tectonics and stratigraphy is mainly based on those geoscientific data-base. Notable contributions to the stratigraphy and tectonics of the shelf areas in Assam and Meghalaya have been made by Evans (1932, 1969, 1964a); Wilson & Metre (1953); Biswas (1961); Mathur and Evans (1964); Metre (1968); Chakraborti (1971); Chakraborti & Baksi (1972) and Dasgupta (1977); the stratigraphy and geological evolution of the basin by Bhandari et al. (1973); Raju (1968); Goswami (1960, 1964); Sah & Dutta (1966); Dutta (1982, 1983); on oil prospects of Assam shelf and its adjoining parts have been dealt with in detail by Murty (1983); Ranga Rao (1983); Desikachar (1984); Rao and Rajkumar (1987); Handique (1993). More recently, a summarized account on "Geology of Assam" written by Dasgupta and Biswas (2000) has been published in a book form and this is a significant and valuable contribution to the geoscientific work on the Tertiary sequence of N.E. India. So much has been written on the geology, tectonics and stratigraphy of the petroliferous basins of N.E. India, one shies at the thought of adding anything new in the subject. But the critical examination of all the available and relevant geoscientific data concerning the stratigraphy and tectonics of the region points to the fact that some controversies and doubts still exist in certain parts of the Paleogene stratigraphy of the shelf areas in Assam and Meghalaya (Dasgupta 1977, 1986).

The object of this paper is to discuss some of the confusions in the course of reviewing the stratigraphic status and nomenclature concerning to Langpar, Basal Sandstone Formations, Jaintia and Barail Groups of Paleogene shelf facies in Assam and Meghalaya. The important and relevant published literature and some unpublished data used in preparing the paper is given at the end of the paper and the broad geological framework of the shelf zone is shown in Fig 1.

CLASSIFICATION AND NOMENCLATURE:

Evans (1932); Mathur and Evans (1964) classified the Tertiary sequences into series and stages according to chronostratigraphic terms although the subdivisions were based mainly on lithological characters with little help from fossils. Precise age for the litho units could not be ascertained due to paucity of age diagnostic fossils except few fossiliferous horizons. When biostratigraphic zonations for the units were attempted based on faunal and floral evidences, many stratigraphic confusions came to light. In some cases, coincidence of many rock units with biostratigraphic zones as well as divergence between the comparable units led to serious problems when a unified scheme for a generalized stratigraphic succession was attempted.

Generally the concept of according lithostratigraphic status for the Tertiary sequence was favoured by most workers as it was established that the entire sequence can further be divided intodistinct groups, formations and members on the basis of gross lithologic characters, heavy mineral zones, electric and other log properties. Evans (1932, 1959) worked out a detailed classification of the both shelf and geosynclinal facies of Assam and Meghalaya. Based on the broad framework of Evans (1932) classification, later workers put forward many schemes of classification with introduction ofnew stratigraphic names and regrouping the various rock units. The evolution of the schemes of classification from Evans (1932) work to the present day necessitated by accrual of sub-surface data and additional information of resurvey and mapping and better understanding of the characters of the stratigraphic units has been shown in Table-1.

A perusal of the table clearly shows that there are many irregularies in the Tertiary stratigraphic classifications especially in the Paleogene sequence of the shelf facies viz. different names has been introduced for the same lithounits, same name has been used for different lithounits and sometimes an indivisual rock-unit has been placed at different stratigraphic positions. Some of the confusions still remaining in the Tertiary succession

IN ASSAM AND MEGHALAYA ARE DISCUSSED BELOW:

1. Evans (1932) used –

a) the chronostratigraphic terminology for litho stratigraphic units.
b) Kopili Stage for the upper most unit of the Jaintia Series.
c) placed Langpar band and overlying Cherra Sandstone in the Cretaceous.
d) not mentioned the Therria Stage at the base of the Sylhet Limestone Stage.

e) not classified the Barail.

2. Mathur and Evans (1964) have –
a) used chronostratigraphic terms for shelf and geosynclinal facies.
b) named the base of the Tertiary sequence of Upper Assam as Disang Series.
c) named Kopili Alternations for the upper most unit of the Jaintia Series.
d) not subdivided the Barail.

3. Bhandari et al. (1973) have –
a) named the Eocene-Oligocene lithotypes as Naga Super Group.
b) named the Early Palaeocene to Early Eocene rock type as Teok Formation of Jaintia Group.
c) divided the Barail Group into Naogaon Sandstone and Rudrasagar Formation.

4. Sinha et al. (1982) have –
a) named the basal lithotype of the sequence as Shella Formation of Eocene age.
b) divided the Barail Group into Laisong, Jenum and Renji Formations.

5. Dutta (1982) has –
a) assigned the suspected Langpar sandstone of Danian age at the base of the Tertiary sequence which is conformably overlain by the Lower Paleocene Therria Formation.
b) equated the Jaintia Group to Disang Group of Eocene age and divided it into Umlatodoh Limestone, Narpuh Sandstone and Prang Limestone.
c) divided the Barail Group into Naogaon, Baragolai and Tikak Parbat Formations.
d) described the lithotypes below the Kopili Formation as shelf sediments and the above including Kopilis as geosynclinal sediments.

6. Singh et al. (1986) have –
a) marked the Tertiary base as Basal Sandstone Formation of Early Eocene age.
b) identified an unconformity between Basal Sandstone Formation and Sylhet Formation (Middle Eocene).

7. Handique et al. (1989) have –
a) named the Therria Formation as Therria Group and placed it at the base of the Tertiary sequence assigning a Palaeocene-Eocene age.

8. Roy and Asthana (1989) have –
a) designated the base of the sequence as Tura/Basal Sandstone Formation of Early Eocene age.
b) not divided the Sylhet Limestone Formation.
c) divided the Barail Group into Arenaccous and Coal-Shale facies.

9. Kar et al. (1984) have –
a) not mentioned any age for the lithotypes.
b) put Sylhet Formation at the base of the Tertiary sequence.
c) divided the Barail Group into Moran and Tinali Formations.

10.Mallick et al. (1998) have –
a) used the chronostratigraphic terminology for lithostratigraphic units.
b) placed the Langpar Formation at the base of the sequence and assigned it to Upper Paleocene age .
c) divided the Sylhet Formation into Lakadong, Narpuh, Prang Member.

d) assigned the Lakadong Member an Upper Paleocene- Lower Eocene age.
e) pointed out the suspected occurrence of an unconformity between Langpar Formation and Lakadong Member.
f) introduced an unconformity between Sylhet and Kopili Formation.
g) divided the Kopilis into Lower, Middle, and Upper members of Middle to Upper Eocene age.
h) shown the Barails as dichronous and divided it into Tinali (Upper Eocene) and Moran (Lower Oligocene).

As a result, the classifications put forward by various workers do not tally each other and become confusing and difficult to follow. These classifications may help only in detailed local correlation provided uniformity in naming the different formations and members is properly maintained. To avoid further confusion for easy understanding, the classification of Mathur and Evans (1964) with minor modifications has been considered in the present work as this classification is now followed by many workers for its convenience and applicability. To discuss the stratigraphic subdivisions and the nomenclatural treatment of the Paleogene succession in Assam and Meghalaya, the latest information available from published literature, few unpublished reports of O.N.G.C., OIL, some research findings and field reports have been incorporated with due acknowledgment.

LITHOSTRATIGRAPHY:

A composite succession of the surface and sub-surface Paleogene lithostratigraphy of the peripheral foreland basin of Assam and Meghalaya shows the following sequences (Table-2).

The Paleogene shelf sediments in the region overlie on various lithotypes in different part of the foreland basin. In the Shillong - Mikir plateaux fringe, the base of the sequence lies on the Precambrian Basement Complex or Mahadek Formation (Fig.2) and in the Upper Assam shelf, the sequence rests on the Dergaon Formation, an equivalent to Mahadek Formation exposed in the Shillong Plateau fringe. Paleogene sequence of the shelf areas is known as Langpar Formation (Lower Palaeocene/Danian), Jaintia Group (Palaeocene-Eocene) and Barail Group (Oligocene). The equivalent rocks of Jaintia Group in the geosynclinal facies is termed as Disang Group.

Langpar Formation : The lithic unit which overlies the Mahadek Formation is the Langpar Formation. It consist of (i) shale with bands of limestone and argillaceous sandstone (ii) yellowish brown impure limestone and (iii) sandstone and sandy shale with sandy limestone in ascending order. Its equivalent rocks are reported from the subsurface at Dergaon, Jorhat district by O.N.G.C. and at Tengakhat (95 o10/ E : 27o23 / N) and Deohal (95o17/E : 27o25/N) by Oil India Ltd. (OIL) and this occurrence is doubtful (Dutta, 1982). Towards the base, it shows a greenish shale while near the contact with the Mahadek, it consists of earthy, calcareous sandstone. Several thin bands of unfossiliferous limestone are well developed in the upper part in the Lunar and Likha river sections. The top calcareous shale contains both mega and microforaminifera. Biswas (1962) opined that the passage between the Mahadek and Langpar Formations seems to be gradational (Fig.3). The upper contact with the overlying Therria Formation is a conformable one (Fig.4). Ghosh (1940) and Dutta (1964) recognised an unconformity between the earthy band of the Langpar and the overlying Therria. From the disposition of the rock types in different localities, it is apparent that the unconformity is local and impersistent. Biswas (1962) observed that the overlying Therria (=Cherra) Formation pinches out in a southerly direction to merge with the Langpar and is unrepresented as such in Therriaghat section. Field studies show that the northernmost of the Langpar coincides with 25o12/ 30//N latitude. Its easternmost limit appears to be the Lunar River Section (Dutta, 1993). The Langpar rock types in the type area i.e. Nongpriang valle(25o17/N : 91o45/E) is about 65m. thick, while towards south, it exceeds 120m. and in Lumshnong area, it is about 30-40m.
Jaintia Group : The Langpar Formation is conformably overlain by the Jaintia Group of rocks. In the shelf areas, the Jaintia Group is divisible into four to five formations namely Therria, Basal Sandstone, Tura, Sylhet Limestone and Kopili and it is Late Palaeocene to Late Eocene in age. These rocks of the Jaintia Group extend from the southern margin of the Shillong Plateau passes through the Mikir massifs to northeastward in the subsurface of Assam Valley. Therria Formation : Conformably overlying the Langpar Formation is the Therria Formation consisting of two members - a lower limestone member (70m) and an upper well jointed, hard quartzitic sandstone member (30m) with workable coal seams and an extensively bioturbated sandy horizon rich in inchnofossils towards the top (Garg et al. 2000; Fig.5).

This formation is best developed in the Umsohrengnew River section (25o10/ to 25o12/N : 91o46/30// E and around Cherrapunjee in Khasi Hills. It thins out both to the north and south, attaining its maximum thickness of 213m. at Umstew (Fig.6). According to Ghosh (in Pascoe, 1964) the equivalent of the Therria Formation in Therriaghat section is represented by a plant-bearing sandstone underlain by a poorly fossiliferous massive limestone with thin bands of shale at its base and passes into the underlying Langpar Formation. The Therria is entirely missing towards the west of Jadukata River (Chakraborty and Baksi, 1972). Good exposures of the unit are found in lower Cherrapunjee, Therriaghat in Khasi Hills and Mynkre in Jaintia Hills. Its equivalents are cropping out in Garo Hills, Mikir Hills, while in the subcrops, it is recorded from Jorhat, Sibsagar and Dibrugarh, Tinsukia districts of Assam. The basal coal-bearing sandstone of the Mikir Hills has been considered to be equivalent of Therria Formation. It rarely exceeds 50m. in thickness and is often overlapped by the overlying limestone which rests directly on the basement complex. Basal Sandstone Formation : Fuloria et al. (1969) named the predominantly arenaceous sediments resting directly over the basement as Basal Sandstone Formation.

The Formation is overlain by the Sylhet Limestone Formation. This sequence has been recorded at Dergaon well by O.N.G.C., where it overlies the Dergaon Formation of Upper Cretaceous age. But Bhandari et al. (1973) preferred it as "Teok Formation".

Lithologically the lower part of this unit consists of granite wash with thin conglomerate band at the base. The upper part comprises mainly coarse to medium grained gritty kaolinitic sandstone and carbonaceous shale.

In the area under OIL, this sequence is described as Therria Formation (Mathur and Evans, 1964). It is possible that lower part is equivalent to Therria Formation while upper part is of Lakadong Sandstone. The Basal Sandstone (Upper Palaeocene-Lower Eocene) forms the basal part of the Paleogene sequence of the Upper Assam basin. In Makum, Rajali, Khowang areas of Upper Assam, it is mainly consisting of alternations of coarse to medium grained sandstone and dark grey splintery shale, whitish clay occasionally present within shales (Borgohain et al., 1999). Barman and Bhattacharyya (1987) reported workable coal seams in the Basal Sandstone exposed in the Sheelvetta and Koilajan area in North Cachar - Mikir Hills of Assam.

Sylhet Limstone Formation : The Therria Formation is succeeded by the Sylhet Limestone Formation which consists of alternating lithounits of limestones and sugary white, ferruginous sandstones with workable coal seams. This unit has been divided into five members in ascending order : namely Lakadong Limestone, Lakadong Sandstone,
Umlatodoh Limestone, Narpuh and Prang Limestone members. The most complete section of the formation is observed between 74 mile post hear Mynkre and 85/5 mile post near Tongseng on the Jowai-Badarpur Road section in Jaintia Hills. Good exposures of the Sylhet Limestone Formation is found in different sections from Sohrarim (27 mile post) to Mawmluh (33 mile post, Fig.7) on the Shillong-Cherra Road. They are also observed around Ishamati – Mawlong, Bholaganj area in south Cherrapunjee. Their equivalents are found in Garo Hills on the west and known differently as Tura Formation, Siju Limestone, Rewak Formation. The Sylhet Limestone Formation has been traced in the Garo, Khasi, Jaintia Hills on the south, northeastwards to the Mikir Hills and also has been encountered in the deep oil wells in Upper Assam shelf; a thickness of about 400m. has been proved (Mathur and Evans, 1964). In the oil field areas, there is no marked lateral variation in lithology, but the thickness increases east ward from 90m. at Rudrasagar to 270m. at Naharkatiya. The formation grades upwards into the Kopili Formation. It was deposited in a shallow, open marine, warm water environment (Bhandari et al. 1973; Dutta, 1993).

Lakadong Limestone : This basal member conformably overlies the Therria Formation in the Khasi Hills and Jaintia Hills. It consists of grey to pink, hard, massive and cryptocrystalline limestone, highly fossiliferous and traversed by calcite veins. There is a thin calcareous sandstone band towards the top. It grades into calcareous sandstone towards top. This is observed in a section near Lumshnong I.B.(Fig.8). The type section was described in the Lakadong (25o11/N : 92o16/30//E) Plateau and also at Therriaghat (25o10/40//N : 91o45/15//E) in the Khasi Hills (Nagappa, 1954). In the Jadukata River Section, the coal bearing Tura Formation rests on the Lakadong Limestone (Chakraborty, et al. 1972) and the latter in turn is underlain by Mahadek Formation without the intervention of the Langpar beds. In the oilfield areas, the Therria - Lakadong unit rests conformably on the Basal Sandstone Formation.

` A 144m. thick unit of alternating sequence of shale and sandstone together with sporadic occurrence of limestone bands are designated as Therria - Lakadong unit without separate demarcation. Fossiliferous limestone bands are recorded only in Bhekulajan and Khowang area. The thickness of the sequence decreases from the northeastern to the southeastern (i.e. Borhapjan to Khowang) part of Upper Assam shelf (Borgohain et al. 1999; Table-3). Tura Sandstone For ation : The coal-bearing lithounit extensively developed in the Garo Hills was named as "Tura Sandstone Stage" after the Tura Range (25 o31/N : 90o15/E) by Fox (in Heron, 1937). It is characterized by coarse to medium grained, current bedded, non-feldspathic, coal-bearing sandstones and lithomargic clays with limestone, grayish-white shale, carbonaceous shale and coal (Fig.9). Three coal seams occur in the Tura Sandstone of which, the middle one is workable. Very thick sandstone beds (20-30m thick) are often associated with whitish lithomargic clay or grey laminated shales. This formation rests unconformably on the kaolinised floor of gneisses in the Garo Hills(Fig.10), except in the Jadukata River Section to the southeast where the Tura is either directly underlain by Mahadek sandstones or by the Lakadong Limestone without the intervention of the Langpar beds (GSI, 1989). This unit is gradationally everlain by the Siju Limestone Member (Fig.11) of the Sylhet Limestone Formation. The Tura Sandstone shows three distinct lithological units (Sah and Singh, 1974) :- False bedded ferruginous sandstone often pebby near the base (40-60m thick) - White or grey shales and / or variegated Lithomargic clays with coal seams (40-60m)- Coarse white clayey sandstone with a pebbly band generally present at the base but sometimes occurs at about 15-30m. above that level (40-60m). The thickness of the formation is variable from one section to the other, it is 400m. thick in the eastern Garo Hills but thinner towards west, 90m. It is also encountered in the subsurface section of the Baghmara well (about 570m). On field evidence, the stratigraphic base of the Tura is now placed at par with the coal-bearing Lakadong Sandstone of Cherrapunjee Plateau (Chakraborty and Baski, 1972). Subsurface data from the Langrin coalfield shows the presence of three to four impersistent limestone beds within the Tura at varying stratigraphic level (Sengupta, 1987; GSI, 1989). Some invertebrate fossils doubtfully dated as Lower Eocene have been recovered from the upper strata of the Tura (Quddus, 1963). Palynofloral elements suggest a near-shore shallow marine environment (Saxena et al., 1995). Ghosh (1940) and Krishnan (1968) equated the Tura with the Middle Sylhet Limestone of Khasi Hills, Meghalaya.

Lakadong Sandstone : The Lakadong Sandstone conformably overlies the Lakadong Limestone in the Khasi and Jaintia Hills. This contact is traceable over a long distance and well observed at Mynkre, Wiser, Musianglamare and Lumshnong (Fig.12). The upper contact with the overlying Umlatodoh Limestone is also conformable. The arenaceous unit consists of fine to medium grained, ferruginous, well bedded sandstones with clays and coal seams. The coal seams are worked in Siropi, Musianglamare, Lumshnong, Bapung in Jaintia Hills and Cherrapunjee-Mawmluh, Mawlong, Laitra in Khasi Hills. The carbonaceous shale in the coal seam section shows some imperfect leaf impressions. A part of the Tura Formation is equated with this member. The palynofossils suggest a coastal aspect and near shore condition of deposition.

Umlatodoh Limestone : The next higher member of the Sylhet Limestone Formation is the Umlatodoh Limestone. The lower contact with the coal bearing Lakadong sandstoneis conformable. It shows interbanding with sandstone and shale both near the lower andupper contact. The limestone is well bedded, highly jointed, hard and compact and highlyfossiliferous. Good exposures of the Umlatodoh Limestone is seen from the south of thevillage Siropi (Milestone 75) to near 82/6 milestone on the Shillong-Badarpur Road in theJaintia Hills. In the Khasi Hills, outcrops are seen near Mawlong quarry and Ishamoti onthe Cherra-Shella Road. On the south-west of Lumshnong, the limestones are more or lessin continuous bands. In the Prang River section, west of Lumshnong, it measures about40 metres.

Narpuh and stone : It is conformably underiain by the Umlatodoh Limestone and overlain by the Prang Limestone. It consist of ferrugimous, medium to coarse grained friable sandstone, sometimes white in colour and occasionally black near the contact with the Umlatodoh Limestone. In Lumshnong area of Jaintia Hills, the basal part of it contains thin impersistent coal layer. The Narpuh Sandstone is also met with in the oilfield areas in Jorhat, Sibsagar and Dibrugarh districts of Assam. The variation of thickness of the unit in the Borhapjan, Makum, Rajali, Bhekulajan and Khowang area is from 45.5m - 115.5m. In these areas, fine grained glauconitic calcareous sandstone with shale in the basal and top part of the unit is recorded. The type area named after the Narpuh Reserve forest of the Jaintia Hills in Meghalaya. So far no palynofossil or animalfossil has been recorded from the unit.

The exposures of the member is seen near Thangski and on the western side of milepost 82 on Jowai-Badarpur Road.

Prang Limestone : The Prang Limestone is the uppermost member of the Sylhet Limestone Formation. It is generally grey to bluish grey and sometimes reddish in colour, jointed and breaks in rectangular blocks. Towards the top, the limestone is associated with thickly laminated calcareous sandstone and fossiliferous shale alternations and often contains carbonaceous specks in the sandstone. The weathered one shows brownish colour. It occurs between mile post 82/6 and 34/5 along Jowai-Badarpur Road and extend strike-wise in East-West direction. Beyond 84/5 mile post the limestone disappears below the Kopili Formation. The type area is the Prang River section in Jaintia Hills. Good exposures are seen in Dilai Parbat at Koilajan, Seelbhetta, Ramgaon, Kopili Hydrel project area in North Cachar and Mikir Hills. In the Upper Assam shelf, the Prang Limestone has been recorded in oil wells at Disangmukh, Dikhowmukh and Teok of Sibsagar district (Metre, 1969) and in Moran-Naharkatiya oilfields of Assam. The thickness varies from 43.5m to 84.5m. in the subsurface of Dibrugarh, Tinsukia districts of Assam. The thickness of the unit is decreasing from northeast to south west in the area. The Prang Limestone is regionally developed in most of the shelf areas in Assam and Meghalaya. In the Garo Hills, its equivalent unit is designated as Siju Limestone (200-15m). It conformably overlies the Tura Formation. The type locality is between Siju Artheka and Siju Songmong (25o21/30//N : 90o42/E). This limestone, in surface and subsurface attains a thickness of 75 to 120m though the formation thins rapidly towards west of Tura comprising of calcareous and ferruginous sandstone and shales with 5m. thickness.

It comprise of banded alternations of sandy limestone and calcareous shale at the base and cliff-forming hard massive impure buff colour limestones at the top. It is prolific in foraminifera, algae and few fragmental mollusk. In Baghamara well in Garo Hills, about 190m. of monotonous, organic limestone occurs below the argillaceous Kopili equivalent rocks. Kopili Formation : The Kopili Formation represents the uppermost unit of the Jaintia Group. It comprises alternations of thinly laminated shales with phosphatic nodules, sandstones, limestones and marls. It attains a maximum thickness of 500m. in Jaintia Hills to 270m. in Shella area (Barman, 1967-68). The formation reduces to 40m. in and around Tura with the development of an arenaccous facies. The formation grades upward into the Barail Group of rocks. The type area is after the river Kopili and the Kopili river section of the Kopili-Khorungma (25 026/N : 92045/E) area has been considered as the type section. This formation is well developed in Khasi and Jaintia Hills and to the east, northeast, outcrops of the Kopilis are seen in the Koilajan river section south east of the Koilajan Colliery in Mikir Hills.

In the oilfield areas of Dibrugarh, Tinsukia and Sibsagar district of Assam, the Kopili Formation is also recorded with a maximum thickness of 552.5m. at Borhapjan well. The lithotype in the subsurface is almost similar with the exposed rocks, comprising of monotonous sequence of grey to dark grey splintery shales with calcarcous sandstone, streaks of limestones and coals with leaf impression. In the Garo Hills, the Kopili equivalent lithuunits are named as Rewak Formation (600m). Its type locality was described as that of the Simsang River near the village Rewak (25 o17/30//N : 90o40/E). It is dominantly an argillaceous facies conformably overlying the Siju Limestone with a marker bed at the base. The marker bed is a black shale (30-40m) with profuse phosphatic nodules and pebbles. It is progressively more shaly and thicker towards east in the west Khasi Hills. The associated sandstone are often fine grained, ferruginous, lateritised and current bedded. There seems no marked lateral variation in lithology. The formation is almost uniform in the subsurface and its thickness ranges from 350 to 460m. It is conformably overlain by Naogaon Sandstone of the Barail group. The heavy minerals of the sandstones are characterised by many opaques. The non opaques include tourmaline, zircon, garnet, staurolite, zoisite and andalusite.

Barail Group : The Barail Group consists mainly of arenaceous sedimentary rocks overlying either Disang or Jaintia Group of rocks at different localities. The Barail Group contains workable coal seams and many productive petroliferous beds in Upper Assam.

The thickness of the group increases from northwest to southwest. The Barail can be distinguished from the overlying Surma-Tipam rocks by the abundance of carbonaceous matter.

A thick sequence of alternating hard sandstones and shales was designated as the “Barail Series” by Evans (1932) after the Barail Range which forms the watershed between the Brahmaputra and the Surma valley. Later workers (Bhandari etal. 1973; Dasgupta, 1977; Handique and Dutta, 1981;

Ranga Rao, 1983) used the litho stratigraphic terms for the Barail Group. A major part of Barail Group in Upper Assam is covered under thick alluvium.

In the North Cachar and Mikir Hills, the shelf facies of the Barail Group are primarily massive, coarse grained sandstones with subordinate shale and thin bands of coal. The thickness is about 400m. In the Upper Assam oil fields, Barail Group has two well defined units, the lower unit is arenaceous with occasional shale bands and the upper coal shale unit consists of mudstone, shale with some sandstones and coal (Murty, 1983). In the Dhansiri valley, this group has been divided into two subunits namely Disangmukh and Demulgaon Formations. Recently, the geologists of O.N.G.C.L proposed a classification of Tertieries of Upper Assam where the Barail Group has been divided into three subunits in order of superposition : Disangmukh, Demulgaon and Rudrasagar Formations (Despande et al. 1993). Based on the subsubface data, Evans (1959) subdivided the Barails into three units, the lowest arenaceous unit is followed upward by alternations of sandstone and shales with a few thin coals and oil sands, and the topmost consists of mudstones shales and coal with no pay sands (Table-4). Azad et al. (1971) recognised three lithological units in the subsurface of Naharkatiya oilfield. The lowest unit consists of medium grained sandstones with only thin mudstone and almost devoid of coal. The “Fifth Sand” is restricted to the upper part of this unit. The middle argillaceous sediments include alternating sandstones and mudstones about 300m thick and interpreted as channel deposits (Bhattarchaya and Dutta, 1970). It includes the other pay zones (locally termed as the First, Second, Third and Fourth sands). The uppermost argillaceous beds consist of clay, mudstone, sandy mudstone, calcareous mudstone, clayey shale, numerous thin coals and occasional thin sandstones and marls. Baruah etal. (1992) and Handique (1993) have divided the Barai Group into Tinali and Moran Formations. The lower Moran Formation and some parts of Tinali Formation belong to Oligocene age, major part of the Oligocene being missing due to unconformity. Most of the Tinali Formation belongs to Upper Eocene age.

Bhandari et al. (1973) subdivided the Barail Group into Naogaon Sandstone and Rudrasagar Formation in the subsurface of the oilfields under O.N.G.C. concession. The Naogaon Sandstone Formation consists mainly of sandstone with subordinate shale beds. The sandstone is calcareous, moderately hard and locally shaly and is termed “Barail Main Sand” which is similar to the “Fifth Sand” of Naharkatiya and Moran oil fields. These sandstones are believed to have been deposited as bars, spits and channel sands (Mathur and Evans, 1964). The Rudrasagar Formation overlying the Naogaon Sandstone is characterised by predominantly shale with subordinate lenticular sandstone beds and prominent coal seams. The thick coal seams in the upper part of this formation helps readily on electrologs. The heavy mineral assemblage does not show any marked difference between Nazzogaon Sandstone and Rudrasagar Formation, but in Disangmukh well, a marked increase in frequency of epidote, tourmaline and titanite in the Naogaon Sandstone marks the differentiation easy from the underlying Kopili Formation.In the Dhansiri valley, the Barails are well developed, around 600m. and comprising of a hard massive sandstone at the top with some shales below.

Northeastwards the massive sandstone is overlain by a coal-shale sequence with channel and bar sands. This unit is about 305m. thick in Naharkatiya well-1 and 350m. in Lakwa well-252. This unit has a number of important oil sands and equated with the Baragolais of Makum-Namdang area of Upper Assam (Dasgupta and Biswas, 2000).

The exposed Barail rocks of North Cachar and Mikir Hills has been equated with Laisong Formation of the type area (Evans 1932; Dasgupta and Biswas, 2000). The thickness variation in the oilfield areas of Upper Assam basin is shown in Table-4. In Garo Hills, the Barail known as Kherapara Formation overlie the Kopili shales unconformably. It consists of finely bedded, thin alternations of shale and fine grained clayey sandstone. The type section is named after Kherapara (25 o20/40//N : 90o46/40//E) and is further subdivided into two members with limited mappability (Chakraborty and Baksi, 1972). The lower Darik Member is arenaceous with finely bedded alternations and thick sandstone at the base. The upper Inolgiri Member consists of thinly bedded sandstone grading to shales. The thickness of the formation reduces towards west from 1160 in the Rongra River to about 250m. in the Tura-Dalu Road. The formation as a whole is characterized by continuous occurrence of chloritoid group of heavy minerals (Chakraborty and Baksi, 1972) with abundant opaques. The Kherapara Formation is unconformably overlain by the post-Barail rocks. The unconformity is more pronounced in the western part of the area. Acharyya and Ghosh (in GSI record, 1989) has described the lithounit above the Kopili as Simsang Formation exposed in the Siju Coalfield area of Garo Hills. The Barail rocks in the southern margin of the Shillong Plateau overlying the Kopili shales at the Lunar River section and in this area, a thicker development of sandstones with shales mapped as Laisong/undifferentiated Barails occur with thickness possibly around 1000 to 1500m. (Dasgupta and Biswas, 2000).

DISCUSSION AND CONCLUSION:

During Late Cretaceous - Paleocene time, the Indian plate came in contact with the Eurasian plate and sea-floor spreading along the NW-NE Carlsberg ridge pushed the Indian plate east and northestward towards Burmese plate. This resulted in the opening of the Indian ocean and a shelf zone flanking the Shillong Plateau-Mikir Hills and in Upper Assam formed on a passive continental margin. The Shillong Plateau-Mikir massifs is a roughly east-west Precambrian horst and is fringed on the southern part by Upper Cretaceous - Tertiary shelf sediments. The northeastward extension of this foreland spur (Evans 1959) beneath the Assam shelf as a hidden basement ridge acted as a barrier for the Eocene sea which transgressed the southern flank of the Shillong Plateau, possibly did not extend into Assam shelf except an embayment of Late Cretaceous sea near Jorhat (Murthy, 1993). Most of the basement highs and lows are reflected in the overlying formations. Numerous structural zones trending N-S to NE-SW forming separate tectonic domains with characteristic positional and tectonic history (Nandy, 1976b). The deposition of the Paleocene-Eocene sequence on the shelf under shallow marine, lagoonalto deltaic conditions was primarily controlled by basement tectonics (Dasgupta, 1979; Fig.13). During Late Eocene-Oligocene, cessation of the steady state subduction of Indian plate below the Burmese plate resulted in shallowing of the basin. Thereafter the shelf zone underwent a transition from a shallow marine through restricted marine environment to a deltaic-estuarine conditions (Handique, 1993). \

The end of the Oligocene Barail deposition is marked by a regional upheaval in the shelf zone resulted in a widespread erosional unconformity between the Barail Group and succeeding younger sediments. During post-Barail time, the Upper Assam platform and the contiguous parts were converted into intermontane continental basin, where the Paleogene platform deposits are overlain by the Neogene molasse-type deposits (Raju, 1968). From the foregoing discussion, it is apparent that the foreland shelf zone, an integral part of the Indian plate experienced differential tectonic development due to basement block-faulting dominated by vertical movements(Fig-5). This structural control on the sedimentation is reflected in the contrasting lithofacies characteristics in the Paleogene sequence of the Garo, Khasi, Jaintia and Mikir Hills and also in the contemporaneous rocks in the Assam shelf (Fig.14). The Paleogene sequence of the shelf areas is considered as continuous from Langpar to Barail time without any major break in sedimentation. The most conspicuous regional feature is the post-Barail unconformity which serves as a datum for regional correlation. However, Dasgupta (1986) and Dasgupta and Biswas (2000) reported the suspected occurrence of an unconformity between the Kopili and overlying Barail rocks in the Garo Hills. But Chakraborty (1971),

Chakraborty and Baksi (1972) did not mention any hiatus in marine deposition at the top of the Kopili. As such any break in sedimentation during Late Eocene is not certainly known. Again the base of Langpar is considered by many workers as the Tertiary base. It is reported that west of Jadukata River, the Upper Cretaceous Mahadek Formation occurs below the Lakadong Limestone or the Tura Sandstone without the passage beds of Langpar. But in the east Khasi Hills, there was depositional continuity as the Langpar rests conformably on the Mahadek sandstones. Pandey (1978) suggested that the K-T boundary lies about 11m. below the Mahadek-Langpar formational contact on faunal evidence. If this finding is accepted to be correct then the Langpar must be placed in the base of the Paleogene sequence, not to the Khasi Group of Createaceous age (GSI, 1974). However, the Langpar sea possibly transgressed up to the Lunar River section in the Jaintia Hills (Changkakoti and Barooah, 1964). It is also not reported from the subsurface at Dergaon well by O.N.G.C. The geological age of the Langpar Formation is disputed. Earlier it was dated as Upper Cretaceous but later, it was assigned to the basal Tertiary by Nagappa (1959).

The presence of Langpar over the basement in the subsurface of Upper Assam Valley has been shown in the drilled wells by OIL (Fig.15). However, this occurrence is doubtful because of the limit of Langpar sea beyond the Lunar River section in Jaintia Hills.

The stratigraphic position of Therria (=Cherra) Formation which is sandwitched between the Sylhet Limestone Formation and Langpar Formation is a matter of controversy in the areas west and east of the Cherrapunjee Plateau in Khasi Hills. Murthy et al. (1962) placed the Upper Sandstone in the Sylhet Limestone and relegated the Lower Limestone to the Langpar Formation without proper explanation. The Therria is entirely missing in the west of Langrin area. Sometimes the unit overlaps the older beds and rests directly on the Precambrian rocks in Sohrarim area to the north of Cherrapunjee. In the oil wells drilled by OIL, the Basal Sandstone sequence is recorded as Therria Formation (Mathur and Evans, 1964). It may be possible that the lower part is equivalent to Therria Formation while the upper part is of Lakadong Sandstone. Again, Therria-Lakadong unit overlies the Langpar in the oilfield areas under OIL and as per the stratigraphic code, two names together for the same unit cannot be assigned. The poorer development of the limestones and more shaly makes it difficult to differentiate clearly the litho-contacts. It needs appropriate stratigraphic analysis at finer resolution.

In the subsurface of Dhansiri and Upper Assam Valleys, different nomenclatures are used both by O.N.G.C. and by OIL for the Tura, Basal Sandstone units which overlies immediately the eroded basement (Fig.16). The Tura is considered to be the lateral lithofacies variant of the alternating limestones and sandstones of the Sylhet Limestone Formation in the Shillong Plateau. The base of the Tura is regarded at par with the coal bearing Lakadong Sandstone base in the Garo-Khasi Hills (Chakraborty and Baksi, 1972).

The stratigraphical position of the Tura seems to be above the Sylhet Limestone, so the Basal sandstone as such cannot be taken as the time-equivalent of Tura of Garo Hills. The dual nomenclature adopted by O.N.G.C. and OIL seems to be misleading and confusing one.

The Basal Sandstone containing workable coals has been reported from Sheelvetta- Koilajan area of North Cachar - Mikir Hills of Assam (Barman and Bhattacharyya, 1987). The Sylhet Limestone Formation of the Jaintia Group was named differently as “Shylhet Formation”, “Shella Formation”. In accordance with the stratigraphic code, the well established formation name be retained, so the Sylhet Limestone Formation status should not be changed. The five constituent members possess distinctive lithological characteristics enabling their easy recognition and tracing in widely scattered out crops in the entire Khasi-Jaintia Hills. The base of the limestone horizons can be used as the reference for mapping. In the Garo Hills, west of Jadukata River section, the limestone beds pinches out, while the sandstones increase in thickness at the expense of the limestones. This interfingering nature of the limestones with sandstone and shale diminishes their importance as maker horizons in regional correlation. This kind of problems are still exist in the subsurface section of the oil field areas, where the development of the calcareous facies is sometimes poor (Dasgupta and Biswas, 2000).

The upper limestone member known as Sju Limestone in Garo Hills and as Prang Limestone in other parts has basin-wide development and its stratigraphic position is well established. But the thickness of the limestone unit varies considerably in different basin positions which may possibly in response to oscillations in marine shoreline. The faunal evidence shows progressive younging of the limestone member from east to west in the shelf margins of the Shillong Plateau. (Dasgupta and Biswas, 2000).

The Kopili Formation, a dominantly argillaceous unit is represented by Rewak Formation in Garo Hills and this unit can be well tied up with the Kopili of the type area. The tracing and recording the formation can be carried over through outcrop and subsurface up to the north of hidden basement ridge in seismic sections (Dasgupta et al. 2000). On priority basis, the name Rewak Formation can be dropped.

The top of the Barail Group is marked by a regional unconformity in Assam and Meghalaya shelf areas. Barails in the shelf areas have been classified differently with introduction of new names. There are contradictory view on definition and nomenclature of Barail equivalent rocks in Garo Hills. **The Kherapara Formation with two members :** lower Darik and upper Inolgiri Members (Chakraborty, 1972) in the western part of Garo Hills and to the eastern part, the same unit overlying the Kopili is designated as Simsang Formation (Acharyya and Ghosh, 1966-68). The Barail Group of the type area attains a formation status in Garo, Khasi Hills and further to the southeast in Mikir Hills, the formation status can be retained as the thickness reduced drastically with monotonous lithologic characters and unmappable indivisual units. This is the undifferentiated Barails of the Mikir Hills. The same relationship amongst the indivisual units in the subsurface of Assam oilfield areas is likely to be valid. Here, the Barail Group though lithologically distinct from the underlying Kopili and overlying

Surma-Tipam rocks, yet its thickness has been reduced drastically (Table - 4) due to the unconformity, in comparison to the type localities. Indivisual units are not always distinct entity on electrolog characteristics and occur variously in different stratigraphic positions. The mutual relationship causes problems in subsurface correlation. In the Assam shelf, either dual or tripartite classification of Barail Group is adopted and that too differently in the areas under O.N.G.C. and OIL concession. This different nomenclatural practice by the oil companies complicates the stratigraphical break down of the Barail succession. These subdivisions would help only in local correlation; not in regional stratigraphic analysis. It has been recognised that the detrital composition of the clastic rocks is significantly related to tectonic setting of the source area. Provenance types are seen to yield quite distinctive suites. The constrast in lithofacies of the Paleogene sequence of the shelf zone may be in response to the source area tectonics. But there are disputes regarding the provenance of these sediments. The presence of stable heavy minerals, rock fragments of low grade metamorphic rocks, igneous rocks with reworked older sedimentaries and compositional attributes indicate that during the deposition of the Paleogene sequence in the shelf areas,the source areas experienced only mild tectonism which could not unroof the more metamorphosed core. The Shillong Plateau and Mikir massif situated to the north of the shelf zone must have been the main provenance which undergone positive tectonism since Jurassic time (Murthy et al., 1969). Recycled detrital minerals, reworked Gondwana elements and sedimentary rock fragments in the shelf sediments point to the contributionfrom older sedimentaries of possibly the Arakan-Chin Hills of Burma or a landmass east of Longitude 89030/E in the Eastern Himalayas or in the region of Shan Plateau and the geanticlinal belt of Arakan Yoma (Mathur and Evans, 1964; Raju, 1968; Desikachar, 1974). The heavy mineral suite of the exposed rocks are similar to their time equivalents in the subsurface of the Assam oilfields and these findings point to a similar terrigenous mineralogical province for the shelf facies (Sinha et al., 1973). Finally, the foregoing discussion has helped to arrive at some significant conclusions:

(i) The stratigraphic classification of the Paleogene shelf sediments in Assam and Meghalaya must be based on gross lithologic characters irrespective of time connotations. It would help if the lithostratigraphic nomenclature is kept confined to the lithostratigraphic units and every effort must be made to avoid extending these units across the regional unconformities.

(ii) The Langpar Formation has been considered to be the base of the Tertiary in Assam and Meghalaya shelf areas and accepted by many workers. The limit of the Langpar exposure is not beyond Lunar River section in Jaintia Hills, hence the reported occurrence of the Langpar in the subsurface of the Assam oilfield areas is doubtfu .

(iii) The Tura Sandstone Formation is a well established lithostratigraphic unit in Garo Hills, representing the lateral lithofacies variant of the Lakadong Sandstoneto Narpuh Sandstone Members of the Sylhet Limestone Formation. In the oilfield areas under O.N.G.C. concession, the Tura Sandstone forms the basal unit underlying the Sylhet Limestone Formation. This appears to be the misnomer in terms of the stratigraphic status and order of superposition.

(iv) The Basal Sandstone Formation was proposed by Fuloria et al. (1969) for the lowermost unit of the Paleogene sequence in oilfield areas of Upper Assam. It is placed below the Sylhet Limestone Formation, resting directly over the Precambrian basement rocks. Its equivalent may be either Therria Formation or the Lakading Sandstone. Until the proper stratigraphic status of this unit be resolved, it must be considered to be an formal unit. It is regarded as the equivalent of "Teok Sandstone" as referred by Bhandari et al. (1973). Considering its stratigraphic relationship with the overlying Sylhet Limestone Formation, it should not be regarded as the time equivalent of the Tura Sandstone.

(v) The Jaintia Group comprises of four defined lithostratigraphic unit namely Therria, Sylhet Limestone, Tura and Kopili formations. The Sylhet Limestone Formation include Lakadong Limestone, Lakadong Sandstone, Umlatodoh limestone, Narpuh Sandstone and Prang Limestone Members. This subdivisions may be retained as per priority rule and as well established units. The uppermost limestone member has a basin-wide distribution and are represented by Siju Limestone in Garo Hills and by Prang Limestone in Khasi-Jaintia and Mikir Hills and in the subsurface of Upper Assam. On priority basis and the great lateral continuity make the Prang Limestone member to be the most formal name. The Siju Limestone may be dropped. The argillaceous unit overlying the Prang Limestone has wide distribution in the region, named as Kopili Formation. In the subsurface of Dhansiri and Upper Assam Valleys, it is divided into two informal members - Charali and Amguri units.

Rewak Formation recognised only in Garo Hills may be dropped as per priority rule and already well established formally proposed unit.

(vi) In evolving a unified scheme of stratigraphic classification for Barail succession, proliferation of many new names for the same lithostratigraphic unit came to notice. In the Assam shelf, many informal names are in usage such as Tinali, Moran, Rudrasagar, Disangmukh, Demulgaon Formations. These lithostratigraphic names have their own merits in local correlation but due to lack of precise definition, lateral continuity, homogeneity and mappability, these units should be treated as informal names for the Barail Group. Until justified in terms of the well established litho-units of the type area or type locality, these names should be discontinued and the tripartite classification after Evans (1959) seems to be adequate for uniformity in practice in the oilfield areas under

O.N.G.C. and OIL.

(vii) The post-Barail unconformity at the top of the Paleogene shelf sequence is considered to be the datum for regional correlation. A minor local unconformity between the Kopili and the Barail is not ruled out.

(viii) A unified lithostratigraphic classification has been proposed for regional stratigraphic analysis of the Paleogene shelf sediments in Assam and Meghalaya.

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Table-1 : Paleogene Succession of Shelf sequences in Meghalaya and Assam as proposed by different workers

Age	Evans (1932)	Wilson & Metre (1953)	Evans (1959)	Mathur & Evans (1964)	Bhandari et. Al (1973)	Murthy et. Al (1976)	Dasgupta (1977)	Raju & Mathur (1995)	Present unified classification		
									Garo Hills	Khasi & Jaintia Hills	Assam Shelf Up. Assam & Dhansiri Valley
Oligocene	U Barail Series	U Barail Series	U Barail Series	U Barail Series	U BARAIL Gr. Rudrasagar Fm. Nagaon Fm.	U	U Barail Series (Not Sub-divided)	U BARAIL Gr. Moran Fm. Tinali Fm.	U Barail Group (undifferentiated)	U Barail Group (undifferentiated)	U Barail Group Argillaceous Unit Alternation Unit Arenaceous Unit
Eocene	JAINTIA SERIES Kopili Stage	Kopili Alternations	Kopili Stage	Kopili Alternations	Kopili Fm.	JAINTIA GROUP Kopili Fm.	Kopili Stage	Kopili Fm. Up. Member Mid. Member Lr. Member	Kopili Fm.	Kopili Fm.	Kopili Fm.
	Sylhet Limestone Stage	SYLHET L. St. Prang L.S. Narpuh S.S. Umlatodoh L.S. Lakadong S.S. Lakadong L.S.	Sylhet Limestone Stage	Sylhet Limestone Stage	JAINTIA Sylhet Limestone Fm.	SHELLA Fm. Up. Sylhet Ls. Member Up. Sylhet Ss. Member Mid. Sylhet Ls. Member Mid. Sylhet Ss. Member Lr. Sylhet Ls. Member	SYLHET LS STAGE Prang L.S. Narpuh S.S. Umlahtodoh L.S. Lakadong S.S. Lakadong L.S.	U Prang Member SYLHET Fm. Narpuh Member Lakadong Member	Prang Ls. Member Tura Sandstone Fm. Lapadang Ls. Member	SYLHET Fm. Prang Ls. Member Narpuh Ss. Member Umlatodoh Ls. Member Lakadong Ss. Member Lakadong Ls. Member	Prang Ls. Member Narpuh Ss. Member Lakadong Ss. Member Basal Sandston Fm.
		TURA St. Up. Therria Sub-stage Lr. Therria Sub-stage U		Therria Stage	U GROUP Teok Fm. U	Lower Sylhet Ss. Member	TherriaS.S. Therria L.S.			Therria Fm.	
Upper Cretaceous	Cherra Sandstone Langpar Band	Cretaceous Rocks				Langpar Fm.	Langpar Stage	Langpar Fm.		Langpar Fm.	
	Mahadeo Beds Bottom Conglomerate					KHASI Gr. Mahadek Fm. Bottom Conglomerate Jadukata Fm.	Mahadek Stage		Mahadek Fm.	Mahadek Fm.	Dergaon Fm.

Group	Formation	Age/ Member	Lithological Characteristics	Heavy Mineral Assemblage	Electrolog Characteristics/ Salinity	Thickness of Formations in metres	Remarks Depositional Environment and thickness variations etc.
BARAIL	Not Divided	(Oligocene)	Barail top is marked by the appearance of blush grey mudstone and spherulitic concretions. The argillaceous unit includes mudstones, shales and coal with thin sandstone. The alternations unit consists of sandstone, shale, thin coals and oilsands and the lowest arenaceous unit by medium to finegrained sandstones with thin mudstones, almost devoid of coal.	Higher percentage of opaques. Persistent garnet zircon, tourmaline, rutile, sphene, Epidote, hornblande thin gastratite, sillimanite absent. In sandstone garnet percentage increases while in shale decreases. Reworked grains are common.	Coal beds show higher resistivity (50-100ohms/m) and low SP. About 5ohms m^2/m in mudstone section 10-20ohms m^2/m in Barail water bearing sands salinity 3500-4000 ppm. Display coarsening upward (funnel shaped) log character.	Thickness of the group has a general trend to increase from NW to SE. 300 – 650 m. 330 – 600 m.	Prograding deltaic sedimentation regressive phase. Barrie bards distributary mouth bars channel sands and marshy or lagoonal facies. Sheet sand, lobate sand geometry.
JAINTIA	KOPILI	(Upper Eocene)	Alternating beds of splintery shale/siltstone with thin to thick sandstone and thin limestone stringers. The siltstone/shale is dark grey, hard and splintery. The sandstones are quartise and greywacke type and sometimes calcareous.	Abundant opaque minerals. Sporadic non-opaques including garnet, tourmaline zircon, rutile and rare staurolite, zoisite andalusite.	Shales are characterised by low resistivity (>3 ohms/m) and the sandstone has a well developed negative SP (–50 mv) and the resistivity of the order of 15 ohms/m.	In the sub-surface thick-ness varies from 350 – 460m. 280 – 550m. 300 – 500m. 370 – 500m.	Unstable shelf facies with tidal influence. Coastal bartype and channel type sand geometry. Shallow marine inner neritic to middle neritic.
	SYLHET	Prang Limestone (Middle Eocene)	Characteristics by shale/ siltstone with interbedded limestone and minor sandstones. Limestones are silty or sandy, dark grey to off-white.	-------	Higher resistivity and very low SP.	60 – 130m.	Shallow, open marine warm-water environment.

Group	Formation	Age/ Member	Lithological Characteristics	Heavy Mineral Assemblage	Electrolog Characteristics/ Salinity	Thickness of Formations in metres	Remarks
	LIMESTONE	Narpuh (Middle Eocene)	Interbedded shale, sandstone, occasionally Limestone in the lower part. The shale/siltstone in the upper part is dark grey, to reddish brown, locally calcareous, glauconitic.	---------	----------	65 – 220m	Shallow marine ranging from neritic to outer neritic.
		Lakadong Sandstone (Upper Paleocene)	Medium to coarse-grained feldspathic sandstone, occasion-ally ferruginous, with thin shales lamination and coal seams.	----------	Sandstone have high negative SP (–50mv), high resis-tivity (25ohms/m) and shales have resistivity less than 5ohms/m.	---------	---------
	THERRIA	Basal Sandstone (Paleocene to Early Eocene)	Lower part consists of granite wash with a thin conglomerate at base. Upper section contains girt, coarse to medium grained Kaolimitic sandstone and carbonaceous shale and coals. Poorly fossiliferous solitary occurrence of limestone based at Khowang well.	Abundant opaques and poor yield of non-opaques. Tourmaline, zircon, garnet, staurolite epidote, rutile and sphene in order of abundance. Rutile, hornblende and garnet are dominating, kyanite, apatite augite are rare. Hypersthene reported.	----------	Its thickness ranges between 70 – 90m, however, it reduced to 12m in the south west of Borholla.	Shallow manrine to paralic environ-ment.
		Therria + Lakadong (Lower Paleocene to Upper Paleocene)	Alternative shale and sandstone, with occasional limestone bands.	Zircon, tourmaline rutile dominant, whereas garnet, hornblende hypersthene, epidote augite, kyanite, sillimanite, diopside brookite, titanite and manganite are rare.	----------	Thickness increa-ses from south western to north eastern part of the subsurface in Dibrugarh and Tinsukia district of Upper Assam.	----------

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Table – 3 : Thickness variation of the Paleogene sequence (in mtrs.) in the subsurface of Assam Shelf

Group/ Formation	Locality –>	Teok	Dikhowmukh	Rudra Sagar	Lakwa	Moran	Naharkatiya	Disangmukh	Naginijan	Galeki	Amguri	Khowang	Makum	Borhapjan	Bhekulajan	Rajaali
Barail Group	Argillaceous (Coal Shale Unit)	121-258	79-114	119-334	199-524	106-423	26-352	105	55	418	–	66.5	123	83	–	–
	*	(330-513)	(510)	(500-630)	(750)	–	–	(606)	–	–	(330-600)	92	130.5	144	–	–
	Arenaceous Unit	209-392	173-234	218-248	204-318	365-488	300-665	260	214	181	–	–	–	–	–	–
Kopili Formation		(346-393)	(300)	(360)	–	–	–	(184)	–	–	(370-500)	–	–	–	–	–
Sylhet Limestone Formation		(114-145)	(115)	(100)	–	–	–	(150)	–	–	(150)	–	–	–	–	–
		–	–	–	–	–	–	–	–	–	(80-100)	–	–	–	–	–
Basal Sandstone Formation 123 m.		–	–	–	–	–	–	–	–	–	–	–	–	–	31	99 m.
Therria+ Lakadong 144 m.		–	–	–	–	–	–	–	–	–	–	–	–	–	106.5	131.5

* **Range in thickness within parenthesis.**

Table – 4 : The Barail Succession (Oligocene) in Oilfield areas of Upper Assam

Age	Evans (1932)	Evans (1959)	Dutta and Bhattacharyya (1968)	Azad et. al. (1971)	Murty (1983)	Bhandari et. al. (1973)	Mathur and Evans (1964)	Handique (1993)	Patil et. al. (1993)
	Geosynclinal Areas (Naga Hills)	**Shelf areas**							
		NHK[1]+MRN[2]	**NHK**	**NHK**					
OLIGOCENE	Tikak Parbat Stage (600m)	Argillaceous Stage	Argillaceous beds	Mainly argillaceous beds 10-100 m	Coal shale unit	Rudra sagar Formation 30-520 m		Moran Formation (Argillace-ous unit)	Barail coal shale (BCS)
	Baragolai Stage (330 m)	Alternations of sandstone and shale with a few thin coals	Alternation beds	Alternations of sandstone and mudstone 300 m	Arenaceous unit	Naogaon Ss. Formation 180-670 m	Barail series (Undivided) 1200 m	Tinali Formation (Arenaceous unit) 300-650 m	Barail sand shale (BSS)
	Naogaon Stage (2200 m)	Arenaceous Stage	Arenaceous beds	Arenaceous group, 600 m					Barail Main sand (BMS)

1. **Naharkatiya Oilfield** 2. **Moran Oilfield**

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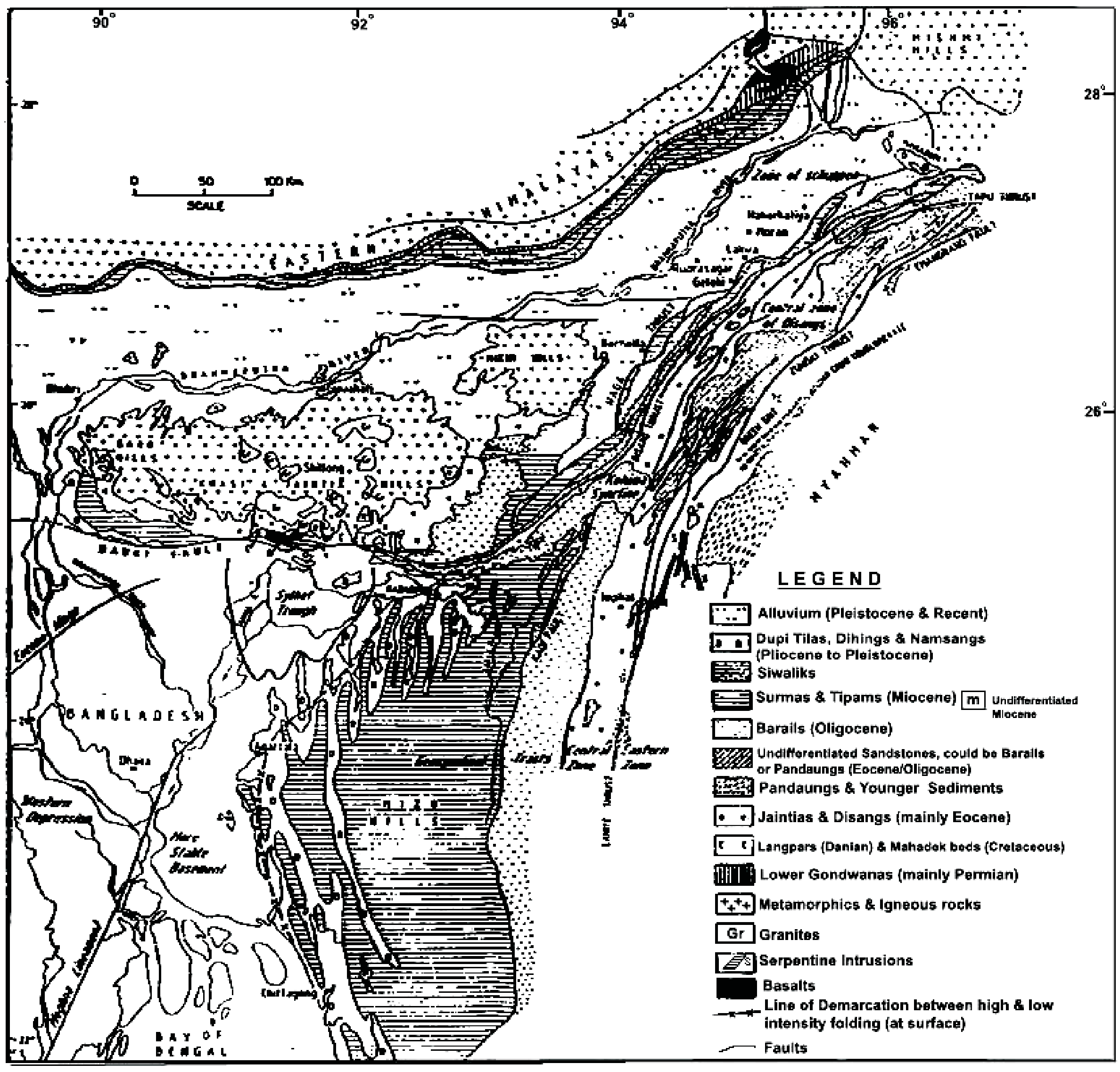

FIG. 1. GEOLOGICAL MAP OF NORTH EASTERN INDIA (AFTER DASGUPTA, 1977)

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