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A Review of Stratigraphy of parts of Upper Assam Shelf & Mizoram

Abstract

The acreage of Oil India Limited is around 8800 sq km in NE India including the states of Assam, Arunachal Pradesh and Mizoram. The area falls under Assam Arakan Basin which is a Category-I petroliferous basin of India with established commercial production of hydrocarbon. While areas of Assam falls in the Upper Assam Shelf and little portion of Dhansiri Valley (Karbi Anglong District), Arunachal and Mizoram fall in the Naga Schuppen Belt and Assam Arakan Fold Belt (Surma Valley) respectively. The basin is a geologically complex one and the regional stratigraphy of the broad area is not well defined with lots of mystification in nomenclature of various stratigraphic units. An attempt has been made in this study to formulate the stratigraphic sequence of NE India where Oil India Limited (OIL) is operating by dividing it into several units (both chronostratigraphic and lithostratigraphic) based on integrated study of lithology, micropaleontology, palynology, wireline log response of the wells drilled and available seismic data. Notable contributions to stratigraphy and tectonics of Assam made by several pioneer Geoscientists are also taken into account for preparing the same. A critical review has been made to correlate the essential rock-stratigraphic units (lithostratigraphy) with the time stratigraphic terms (chronostratigraphy) within the study area.

Introduction and Geological Setting

Assam Arakan Basin encompasses an area of over 1 lakh sq km, of which 57000 sq km, lies in Assam Shelf. OIL's acreage comprising of parts of Assam and Arunachal Pradesh belong to the Upper Assam Shelf and a small part of Naga Schuppen Belt. Mizoram block falls in Assam Arakan Fold Belt (Surma Valley) and Karbi Anglong falls in Dhansiri Valley. Upper Assam Shelf, Dhansiri Valley and Naga Schuppen Belt are three major components of the established petroliferous Basin located in the NE of India. The Assam Arakan Basin is a shelf–slope–basinal system. The shelf part of the basin spreads over the Brahmaputra valley and the Dhansiri valley, the latter lying between the Mikir hills and the Naga foothills. From Digboi, the shelf runs westward to the southern slope of the Shillong plateau. The shelf-to-basinal slope lies below the Naga schuppen belt. The basinal (geosynclinal) part is occupied by the Cachar, Tripura, Mizoram and Manipur fold belts. Geological Map of the Assam Arakan basin with major structural components are given in Fig: 1. The Upper Assam Shelf consists of sedimentary rocks ranging in age from Cenozoic to Recent and are considerably thick, varying from 3.6 to 6.5 km which include shallow marine Paleogene and continental Neogene sediments overlying the granitic Basement.

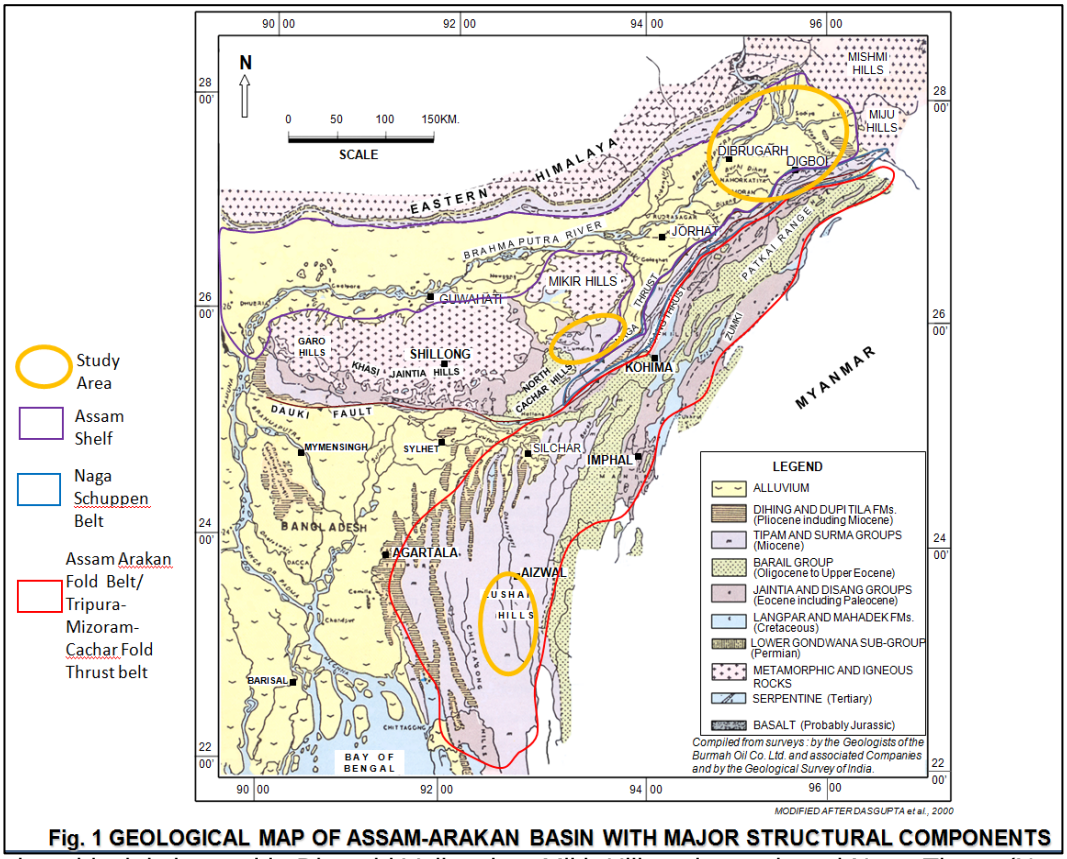

Fig. 1 GEOLOGICAL MAP OF ASSAM-ARAKAN BASIN WITH MAJOR STRUCTURAL COMPONENTS

The Karbi Anglong block is located in Dhansiri Valley, has Mikir Hills to its north and Naga Thrust (Naga – Schuppen belt) to its SE. It is geologically located between Schuppen Belt towards SE and Mikir Hills towards NW. The granitic rocks of Pre-Cambrian age are exposed in major part of Mikir Hills, and Palaeocene and Neogene rocks outcrop at its periphery. The

exposures of mostly Neogene and some Barail sequences overlying the Naga Thrust are seen in western peripheral parts of Naga Hills, adjoining the Dhansiri Valley. Mizoram block falls in Assam Arakan Fold Belt which is also known as Tripura-Mizoram Fold Thrust Belt. It occupies the frontal part of the Assam Arakan orogeny and is characterized by a series of N-S trending anticlines and synclines whose axial traces trend in N-S direction. An effort has been made through this paper to depict a broad regional stratigraphy of the study area with special emphasis on Code of Indian Stratigraphy.

General Stratigraphy

Upper Assam Basin contains 3.5 - 4.5 km of mainly clastic Tertiary sediments. These sediments overlie a Precambrian granitic basement and are commonly buried beneath Pleistocene - Recent alluvium. The pre-Pliocene sediments generally thicken to the south, whilst the post-Pliocene sediments thicken to the north. Thickening patterns reflect discrete changes in basin development.

Stratigraphic sequences of the Upper Assam Shelf basin in the chronological order is described as under

Pre-Tertiary

Evidences of Pre Cambrian rock types are not available in Upper Assam Shelf. It is believed that metamorphics of mainly granitoid gneiss of early Proterozoic age has been found in Shillong Plateau and Mikir Hills. These granitoid gneiss in small masses in the massive deposits of Dihing and alluvial boulder beds in Manabum anticline and other areas near the Mishmi Hills is reported (Dasgupta & Biswas). Oldest fossiliferous sediment in the Upper Assam Plains was found at Dergaon Formation. In the wells drilled, Basement has been encountered in the deep wells ranging in depths from 4000-5500 m where lithology interpreted from drill cuttings being mainly pinkish granitic gneiss with presence of crystalline quartz, feldspar and biotite. Deeper wells proved that the Basement complex extends for many kilometres NE beneath the alluvium or unfolded Tertiary rocks of the Brahmaputra valley and the shelf (Evans, 2009). On wireline logs, the basement complex is characterized by high resistivity (>100 ohm/m) and very low GR and can be distinguished from the overlying strata.

Tertiary

The Tertiary succession of Assam Shelf directly overlies the Archean Basement Complex. The overall Tertiary stratigraphy of the Shelf areas of Upper Assam in chronological order is listed below

Paleogene System of the study area overlies the Pre Cambrian Basement. The shelf facies of the Paleocene-Eocene Series was termed as Jaintia Series and was sub-divided into three Stages, viz. Kopili Alternations, Sylhet Limestones and Therria Sandstone (Mathur and Evans, 1964). However Jaintia Series which is a geochronologic unit was re-designated as Jaintia Group in the sub-surface (lithostratigraphic unit) encompassing the correlative stratigraphic interval of the type area (Bhandari *et al*). Equivalent geochronologic unit was reported as Disang Series (Mallet 1876, Evans 1932, ECL Report 2002).

Langpar Formation (Danian Stage of Lower Paloecene) is believed to be the earliest sediments in Upper Assam Basin & basal unit of Paleocene and it rests unconformably on the granitic basement (Kent & Dasgupta 2004, Mathur *et al* 2001). Lithology of the Langpar Formation is thick, clean, medium to coarse grained massive sandstone with minor shale laminations as encountered from the drilled wells.

Jaintia Group of rocks comformably overlies the Langpar Formation (Sarmah & Borgohain, Kent & Dasgupta). Though Tura Formation is not reported in the Assam shelf, it is encountered in the wells C and T located in Karbi Anglong District falling under Dhansiri Valley. Initially it was believed that Therria Stage of Paleocene age overlies the Langpar Formation (Danian Stage-Early Paleocene), but relationship between the two has not been satisfactorily demonstrated. Because of the more or less similar lithology, Therria Formation (consisting of sandstone, calcareous sandstone, limestone and coal seams) and Lakadong Member of Sylhet Formation are kept together for describing the stratigraphy of the drilled wells of Upper Assam Shelf and are often termed as Lakadong+Therria. Nevertheless, the existence of Therria Formation which is sandwiched between Langpar Formation and Sylhet Formation is not well defined. By considering all the above criteria and honouring stratigraphic code of nomenclature in this study area, it is presumed that Sylhet Formation comformably overlies Langpar Formation within Upper Assam Shelf. The chronostratigraphic equivalent of Langpar Formation may be Lower Paleocene to Lower Eocene Series with Danian to Ypresian Stage.

In Upper Assam Shelf, Sylhet Formation is further sub-divided into Prang, Narpuh and Lakadong Members. Sylhet was the name of the rocks quarried along Khasi-Sylhet border and Therriaghat is the type locality of the Formation. The name is retained for correlative and lithologically similar rocks present in the Assam valley subsurface. Lakadong Member has been kept as simplified one unit and based on lithological characteristics of the drill cuttings, wireline log signatures, depositional environment and hydrocarbon distribution it is further sub divided into three units, viz. heterogenous group, thick sand group and thin sand group (Mathur et al, 2001). This sub-division of Lakadong Member is more or less persistent throughout the Upper Assam Shelf. Members Narpuh and Prang conformably overlies Lakadong Member with average thickness of 100 m and 70 m respectively. The type section for Narpuh is named after Narpuh Reserve Forest of Jayantia Hills and exposures

are well seen in Jowai-Badarpur Road. Narpuh Member consists essentially of very fine grained siltstone with occasional shale and thin band of limestone. Narpuh is overlain by Prang Member which has the lithology of dominantly limestone, fossiliferous in alteration with shale, occasionally silty shale and siltstone. The type area for Prang is the Prang river of Jaintia hills. Sylhet Formation is not sub-divided in Karbi Anglong area and has been kept as a single Formation with a thickeness of 50-200 m having lithology of dominantly Limestone. Time equivalent unit of Sylhet Formation is Middle Eocene Series and Ypresian to Lutetian Stage.

Kopili Formation represents the uppermost unit of Jaintia Group and it overlies Sylhet Formation. The Formation is composed predominantly of splintery shale with few thin alternations of sandstone and marl streaks. Shale beds are fossiliferous and slightly calcareous. Thickness of Kopili is in the range 400-750 m and it increases frm NE to SW of Upper Assam shelf. Chronostratigraphic equivalent of Kopili is Middle Eocene Series and Lutetian to Bartonian Stage. A recent in-house regional study on Kopili prospectivity carried out by suggest that Kopili Formation may be sub-divided into three Members (Lower, Middle and Upper) based on understanding of the depositional environment. Three different and distinct stacking patterns (retrogradational-progradational-progradational) can be observed from the well log signatures. Kopili is kept as single lithostratigraphic unit in Karbi Anglong Area.

Kopili Formation (of Jainitia Group) is overlain by Barail Group of rocks. Barail was given a lithostratigraphic nomenclature “Group” by Bhandari et al. Barail Group is divided into several Formations based on evidences of rock types in different type sections throughout the Assam Valley and Assam Shelf. In Upper Assam Shelf, Barail Group is simplified and is sub-divided into mainy lower Barail Arenaceous unit and upper Barail Argillaceous Unit. Sub-division followed in OIL is widely accepted and is followed in the generalised stratigraphy of the drilled wells. However, in Karbi Anglong area of Dhansiri Valley, Barail (Argillaceous) Formation is not exposed and is thought to be eroded as evidenced from drill cuttings of nearby wells. Hence, Barail Group of rocks in Karbi Anglong consist of only Barail (Arenaceous) Formation with dominant lithology of fine grained sandstone. It is to be noted that thickness of the Barail Group increases considerably from NW to SE in the shelf depending upon magnitude of the unconformable overlap. Based on the evidences of heavy mineral assemblages and Palynology, chronostratigraphic unit of Barail Group is found to be Upper Eocene to Lower Oligocene Series and Priabonian to Rupelian Stage (ISIS Study, 2005).

The Paleogene units were deposited in the shelfal area and existed prior to the collision of West Burma Block with Indian Craton. Basinward, within Assam Arakan Thrust Belt or Naga Schuppen Belt (Part of Geosynclinal Sediments) towards SE, age equivalent of Jaintia Group are referred to as Disang Group. Due to lack of wells, its thickness is not ascertained. From the outcrops, towards SE of the basin, it is made up of monotonous sequence of dark grey shales with thin sandstone beds. The outcrops are trending in ENE-WSW and are well exposed along the Stilwell Road. Barail Group in the Schuppen Belt is subdivided into three Formations, in ascending order; Naogaon, Baragolai and Tikak Parbat (Mathur & Evans, 1964). These form broadly ENE-WSW trending outcrops and are associated with almost every thrust slice in the thrust belt area. The entire succession of Barail Group was encountered and mapped in the outcrops near Namdang River (Dasgupta et al, 1964).

The Neogene succession in the basin starts with Surma Group and in Shelf part with Nahorkatiya Group. Tipam Formation of Naharkotiya Group in Shelf part unconformably overlies Barail Group of rocks. This unconformity (between Oligocene to Miocene) is a widespread break and is first observed in Jaipur Anticline. Across the Naga Thrusts, the unconformity has been recognised in all thrust slices where both Surmas-Tipams and Barails are present.

Surma Group is the lowermost lithostratigraphic unit of Miocene and is a thick succession (5500 m) in Surma Valley and Naga Hills. However it rapidly thins northwards in the shelf area of the basin. Surma may be present in the wells drilled in Jorajan area based on log and seismic signatures which was indicated as Basal Sandstone by OIL geoscientists. However its existence is limited to few wells and are present in the vicinity of Naga Thrust in the Foreland area of the basin. Its lithology is sandstone and subordinate shale, with a thick band of conglomerate and gritty sandstone. However, the contact of Surma Group with the overlying Tipam has remained undefined in both Assam Valley and Plains.

The type area for the Tipam Group is the Jaipur-Digboi anticline at the north-eastern end of Schuppen Zone. The maximum development of Tipam facies is close to the Naga Thrust and include Digboi, Bandersulia and other frontal folds. Throughout the shelf area, Schuppen Belt and Surma Valley, there is a lot of lateral variation from one lithotype to other. As a result, much of the Bhuban and Bokabil Formations which are components of Surma Group of Surma Valley, become lateral equivalents of the Tipam of type area in Assam. The sub-division of Tipam Formation/ Surma Group into Bhuban and Bokabil units are not defined in the Upper Assam shelf and Dhansiri valley.

Another lithostratigraphic unit, named Nahorkatiya Group was proposed by Mathur et al (2001). Nahorkatiya Group consists of Surma, Tipam & Girujan Formations in its chronological order. Tipam was named as Formation and is clastic & particularly sand-dominated unit of Miocene Series found throughout the main basin and to the north of the Disang Thrust in thrust belt. Lithology of Tipam Formation consists of massive sandstones with sub-ordinate shales and clay and is widespread in the shelf area with a thickness of around 2200 m. Based on the evidences of heavy mineral assemblages and Palynology, chronostratigraphic unit of Surma Group is found to be Lower Miocene Series and Aquitanian to Burdigalian Stage. However in Schuppen Belt and Tripura-Cachar-Mizoram fold belt area the chronostratigrahic unit is believed to be the entire Miocene Series (Aquitanian to Messinian Stages). Time stratigraphic equivalent unit for Tipam Formation was

found to be lower/early Miocene Series (Aquitanian to Burdigalian Stage) and that of Girujan Formation was early to middle Miocene Series (Langhian to Serravallian Stage) [Mathur et al (2001)]
Mizoram area is considered as a part of Tripura-Cachar-Mizoram fold thrust belt (FTB) and is also believed to be the part of Surma Valley (Mathur & Evans, 1964). Oldest exposed beds have been referred to as Lower Bhuban. The lithology consists of monotonous shale interbedded with siltstone and occasional feldspathic sandstone with streaks of carbonaceous matter. In most part of Mizoram deeper and older rocks of Upper and Middle Bhuban rocks are exposed. In the eastern extremity of Mizoram, it is likely that rocks of the Lower Bhuban or even Renji Formation of Barail Group may be exposed. Overlying Bokabil Formation has been identified only in the northwestern part of Mizoram in the Langai River syncline. Mizoram is occupied by alternating sandstone and shale units of Upper and Middle Bhuban Formations. Whereas the upper Bhuban units are supposedly dominated by sandstone, the middle Bhuban units are supposed to be shale dominant. Mizoram is often characterized by a series of anticlines with intervening synclines. The rocks of middle Bhuban occupy cores of anticlines and Upper Bhuban Formation is exposed at synclines. Oldest exposed beds in the Mizoram area have been referred to as lower Bhuban Formation. The lithology consists of monotonous shale interbedded with siltstone and occasional feldspathic sandstone with streaks of carbonaceous matter. The succession of the Oligocene Series and Barail Group of rocks (Mathur and Evans, 1964 and Ranga Rao,1983) is sub-divided into Lower Laisong, Jenam and upper Renji Formations. These three Formations are well developed and are recognised in south of Haflong Thrust. Laisong passes gradationally into Jenam which is a predominantly argillaceous sequence of shale and Jenam grades into Renji Formation which is a sandstone unit with increasing proportion of sand. This entire succession was visible in Haflong-Silchar Road with thickness of Laisaong, Jenam and Renji Formations are 885 m, 980 m and 800 m respectively (Ranga Rao, 1983). Though Barail outcrops are not visible anywhere in Mizoram, Renji Formation was encountered in a well drilled at a depth of around 3900 m with sandstone being the dominant lithology with intercalation of shale as shown in the drill cuttings.

In Karbi Anglong Area, Surma Group of rocks entirely consist of Bokabil Formation with the lithology of dominant sandstone interbedded with shale with thickness of around 1500 m. Surma Group is overlain by Tipam Formation consisting of medium grained sandstone. The exposures of mostly Neogene sediments of Tipam & Bokabil and few Barail sequences overlying the Naga Thrust are seen in this area covering western peripheral parts of Naga Hills, adjoining the Dhansiri Valley.

Girujan Formation conformably overlies the Tipam Formation and consists of soft mottled clays containing minor sandstone lenses. “Girujan’’ was named after a small stream near Digboi and was introduced by Evans (1932) for a Formation that is predominantly clay. Thickness of Girujan Formation increases from SW to NE passing through Jorajan, Talap, Mechaki and Sadiya area with range from 720 to 2500 m. However, northwestward, the thickness reduces rapidly over the Nahorkatiya oilfield and Girujans have only thin presence in Tengakhat area and are literally absent in the vicinity of Brahmaputra Arch as evidenced in the drilled wells. Reduction of sedimentary thickness of Girujan towards NW may be because of deep erosion at the end of Tipam deposition. The Girujan clays thus have a significant presence in the shelf zone over only a limited area in the northeastern slopes of the Central Basement High. Girujan thickens into the thrust belt area towards NE where they attain a thickness of more than 1500 m as evidenced in the drilled wells. Increase in thickness in this area in the outer thrust slice (Hanging wall blocks of imbricate thrusts) is at the expense of the Tipam Formation and the latter at the expense of the upper part of the Surmas and Tikak Parbat, both in the north-easterly direction.

Girujan is unconformably overlain by Namsang Formation which consists of poorly consolidated fluvial sandstone with interbedded clay and lignite. The unconformity is of regional extent. Namsang followed a major widespread tectonic activity and overlies Girujan with an unconformable break in the submontane belt. In the Assam Shelf and Naga Schuppen Belt, Namsang is the only Formation which was assumed to be a division of Dupitila Group. However, in Surma Valley/Fold Belt Area it is further divided into lower and upper Dupitila Formations. Lower Dupitilas are confined to the residual depositional area of Kohima Synclinorium. Upper Dupitila Beds of the Namsang Formation is exposed all along the foot of the uplifted central Disang mountians from Langting Valley to the Jaipur anticline. Namsang beds are named after Namsang river- a tributary of Burhidihing river (Das Gupta & Biswas 2000) and are redesignated as Namsang Formation in the sub surface. In the drilled wells, Namsang Formation is evidenced from drill cuttings with the lithology of bluish grey and brownish clay, medium to fine grained sandstone & presence of coal and is encountered immediately after the unconsolidated alluvial sandstone. However, because of the presence of clays in the sequence, these rocks frequently are mistaken for the Girujan. Similarly, it is also difficult to distinguish between Girujan & Namsang from wireline signatures and Namsang can be only recognised from the typical coal bands encountered after the alluvial sandstone. A prominent seismic reflector is obtained from near the top of the Formation, which may be due to a greater degree of consolidation of the Namsang sediments than the overlying alluvial unconsolidated sandstone. Namsangs thicken away from a high at the Central Basement High Area and reach a penetrated thickness greater than 950 m towards SE and nearly 2000 m, NW of Brahmaputra river. Based on the evidences of heavy mineral assemblages chronostratigraphic Unit of Namsang Formation may be Upper/Late Miocene to Lower/Early Pliocene Series and Messinian to Zanclean Stage (Mathur& Evans, 1964).

Namsang Formation is unconformably overlain by Dihing Group of rocks. Dhekiajuli Formation comprising of unconsolidated medium to coarse grained sands with relatively few pebbles & grits and boulder beds are developed locally at the base of Dihing Group. The Formation contains youngest rocks in the sedimentary column lying just below alluvium. This Formation was first encountered below the Naga Thrust and cored in an investigation boring through Jaipur anticline at Dhekiajuli. Subsequently, all the wells drilled in Upper Assam Shelf have encountered this Formation. Dhekiajuli Formation is unconformably overlain by Assam Alluvium of Dihing Group which is predominantly loose, unconsolidated sands with a few

thin clay & silt bed and sparse thin rubble and pebble bands. Alluvial deposits in Assam range from extensive terrace forming boulder beds to sands, silts and clays. The youngest Alluvium forms the present day flood plains which support basic agriculture. Alluvium and Dhekiajuli are characterized by very high resistivity values in wireline logs. In Upper Assam Shelf, its thickness varies from 1300 m in front of Naga Thrust to around 2200 m towards NW in Central Basement High. Further towards NE in Mechaki and Talap area, thickness increase to around 2500 m. The thickness decreases towards SE and wedges out near Naga hills. Geochronologic Unit of Dhekiajuli Formation is Pliocene Series (Zanclean to Piacenzian Stage) and that of Alluvium is Quarternary System/Pleistocene to Recent Series (Gelasian, Calabrian, Middle & Upper Stage).

Biostratigraphic Analysis

KDMIPE, Dehradun, ONGC has carried out micropaleontological studies from the drill cutting samples from the wells drilled in Upper Assam Shelf. In the samples larger benthic foraminifera, microfossils and few elements of smaller benthics are recorded. In few occasions, planktonic foraminifera are also recorded. Preserved fossils range from Early Oligocene (basal part of Barail Group) to Cretaceous (Basement). In some cases, Limestones are highy crystallised so the foraminifera could not be isolated from them and hence ill preserved. Wherever larger foraminifera and planktics are recorded, the age of the sediments have been assigned precisely. Middle Oligocene to Recent ages are devoid of any kind of microfauna except some globular bodies in places. Abundant spore-pollen as well as dinoflagellate cysts were recorded from the samples.

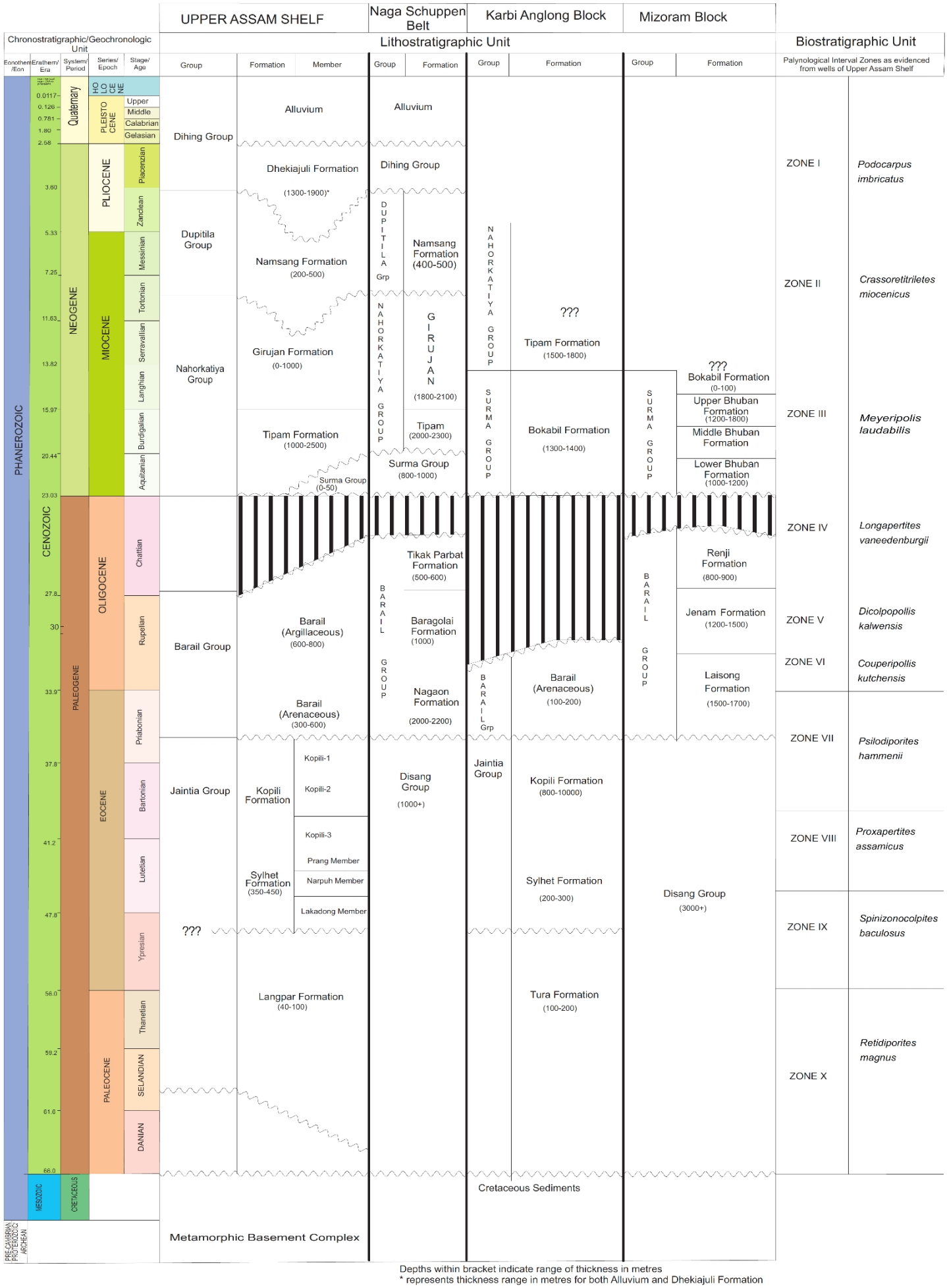

Fig:2 Generalised Stratigraphy of OIL Operational Area

Detail Palynological study was also carried out by KDMIPE, Dehradun, ONGC from the drilled well samples. Abundant spore-pollen as well as dinoflagellate cysts were recorded from the samples. Record of some stratigraphic potential palynofossils helped in determination of age and interpretation of depositional environment. In addition, marine phytoplanktons are also recorded in the Paleocene and Eocene sediments of some of the wells which augment dating of Paleogene sediments with precision. The qualitative and quantitative distribution of selected taxa and disappearance datum of age marker taxa, especially the dinoflagellate cysts, may enable recognition of 10 broad informal palynological interval zones. The zones recognised are more or less similar with the wells located in the NE of Upper Assam Shelf. (viz. areas of South Tinai, Borhapjan, Mechaki, Barekuri, Nahorkatiya and Samdang).

Conclusion and Recommendation

Based on detailed study, stratigraphy of the study area covering Upper Assam (including small portion of Arunachal), Mizoram and Karbi Anglong is portrayed which is given in Fig 2. This stratigraphic understanding may form the basis for all upstream activity from basin exploration through field evaluation to reservoir development and production of the study area.

It has been found that present stratigraphy is mostly based on geological concept arising from existing geological literature and except little bit of micropaleontological and palynological study, there are hardly any methodology used to ascertain the geological ages of the different Formations encountered within OIL's acreages. There were several events where there are significant doubts to correlate the lithostratigraphic unit with the chronostratigraphic unit. The data achieved from drill cutting evidences, seismic data and well log signatures of the drilled wells are giving enormous information on lithostratigraphy, however these are inadequate to correlate the same with the Chronostratigraphic Unit.

Detail micropaleontology study from the drilled wells and utilization of recent age dating techniques viz. Chemostratigraphy, Magnetostratigraphy, Radiometric dating etc. may give significant confidence on Chronostratigraphy of the study area. Furthermore, as Assam, Arunachal Pradesh and Mizoram in most of the parts are surrounded by dense vegetation and hilly terrains, it is difficult to get good field exposures where stratotypes are required to be found out. Hence, wherever stratotypes have found out, these are required to be preserved so that information of a particular bed/stratum/unit may be easily established. Similarly, momentous emphasis may be given for preservation of other geological features viz. contacts between two different strata, presence of unconformities, variation in lithologies, exposures of geological structures like faults/folds/dykes etc. which are easily distinguishable with naked eyes (such as in road cuts, river banks/sections, erosive land masses, extinct open cast mines etc.). This would give enormous information to a Stratigrapher.

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