Petroliferous basins of India

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Introduction

- Indian sedimentary basins cover an aerial extent of about 1.79 million sq. Km, both on land and offshore up to 200m isobaths.
- However, the sedimentary area in deep water beyond the 200m isobaths has been estimated to be about 1.35 million sq. km.
- This makes the total sedimentary basinal area as 3.14 million sq. Km.
- At present, India has 26 sedimentary basins which based on the occurrence of hydrocarbon; exploration and the status of knowledge have been divided into 4 categories.

Category-I

Category-II

Category-III

Category-IV

Category-I

The petroliferous basins with proved hydrocarbon reserves and where commercial production has already been started comes under this category. It mainly includes basins like –

- Assam shelf
- Bombay offshore
- Cambay
- Krishna
- Godavari
- Rajasthan
- Cauvery

Category-II

Sedimentary basin with proved occurrence of hydrocarbons but from which no commercial production has been obtained yet comes under this category. The basins mainly include -

- Andaman Nicobar
- Bengal
- Himalayan foothills
- Jaisalmer
- Kutch
- Mahanadi

Category-III

In this category, sedimentary basins have no significant oil & gas shows but are considered as prospective on Geological considerations. It includes following basins -

- Bikaner- Nagaur
- Kerala- Lakshadweep
- Saurashtra

Category-IV

This is the category, where petroliferous basins with uncertain prospects require basic data for prognosis. It includes the basins, which bear an analogy with similar hydrocarbon producing basins in the world and may be prospective. It includes basins like

- Arunachal Pradesh
- Deccan syncline
- Ganga valley
- Gondwana
- Mizoram
- Manipur
- Narmada
- Vindhyan

Estimated Reserves

Basins Estimated Reserves

BASIN	ONLAND (MMT)	OFFSHORE (MMT)	TOTAL (MMT)
Bombay	9190	-	9190
Assam	-	3180	3180
Cambay	-	2050	2050
Upper Assam	-	1860	1860
Krishna- Godavari	555	575	1130
Cauvery	270	430	300
Rajasthan		380	380
Kutch	550	210	760

Source Rocks

- The fine grained, clay rich siliclastic rocks (mudstone shales) or dark coloured carbonate rocks (limestones, marlstones) which have generated and effectively expelled hydrocarbons are known as the source rock.
- The source rock mainly for petroleum accumulation and generation are shales, silts, and limestones.
- For the characterization of source rock, there are three essential conditions, which are given as follows:
  - **a)** It must consist sufficient content of organic matter of biological origin.
  - **b)** The organic matter that occurs in the source rock must have hydrogen- rich composition.
  - **c)** The source rock must be buried at certain depth where it is subjected to proper temperature to initiate the process of petroleum generation by thermal degradation of kerogen.
- In the source rock of siliclastic and carbonate, minimum concentration levels of 1.5% and 0.5% total organic carbon (TOC) respectively have been established on the basis of empirical evidence.

Reservoir Rocks

- After the generation of petroleum, it migrates from source rocks to the adjacent porous and permeable rocks and accumulates there to form a pool.
- Such permeable rocks are called “Reservoir Rocks”. They contain interconnected passageways of microscopic pores or holes that occupy the areas between the mineral grains of the rock.
- Seals are very fine-grained rock, which have negligible amount of pore spaces, and they do not permits the entry of fluids or blocks the further migration of oil.
- The two important properties of reservoir rock are –
- Porosity
- Permeability

Reservoir Rocks

- ***Porosity*** is the volume of void spaces as percentage of a given total volume of rock. The pore size depends on the rock volume and also on the movement of oil.

- The variety of pore sizes can be measured and expressed as pore-size distribution. There are mainly two types of porosity, primary and secondary (inherited from deposition of sediment or generated by mineral dissolution reactions in the subsurface respectively) and a third type of porosity is fracture porosity caused by tectonic processes.

- ***Permeability*** is the property of rock, which permits the flow of a fluid through the interconnected pores without any change in the structure of the rock, or displacement of its grains is known as permeability or absolute permeability.

- The common reservoir rocks are sandstones, conglomerates, porous limestones, fractured shales, and jointed igneous and metamorphic rocks.

Oil Migration

- The movement of oil from source rock to adjacent porous and permeable reservoir rock is known as the migration of oil.
- Migration of petroleum from its place of origin (source rock) to its place of accumulation (reservoir trap) is controlled by the physical and physico-chemical conditions of the sedimentary strata from which the oil is moving through.
- The weight of the fluid column corresponding to the interconnected network of water-filled pore spaces from a given depth up to the sediment surface is known as the hydrostatic pressure.

The causes for the migration of petroleum are:

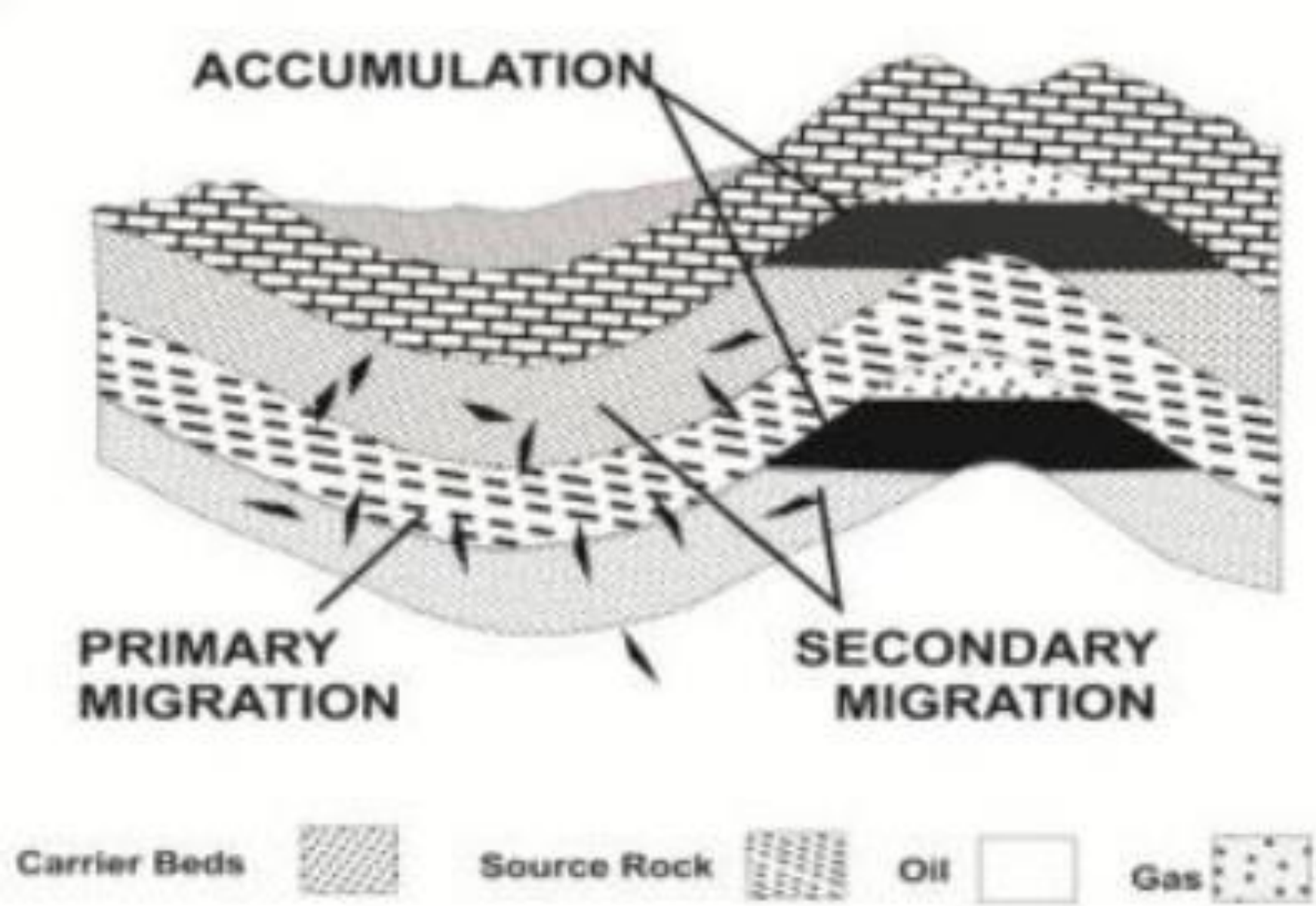
- **Compaction of the source rock**
- **Buoyancy effect**
- **Capillary effect and**
- **Water Flushing**

Types of Migration

There are mainly two types of migration:

- ***Primary Migration-*** In primary migration the movement of oil takes place from source rock to adjacent porous and permeable rocks which are known as the store house of oil (Reservoir rocks).
- In good-quality source rocks, oil is transported as a separate phase.

- ***Secondary Migration-*** The secondary migration is the movement of oil from first reservoir to the second reservoir or on the surface of the earth.
- The movement of a discrete oil phase is controlled by the interplay of driving and counteracting resisting-forces.


ACCUMULATION
PRIMARY MIGRATION
SECONDARY MIGRATION
Carrier Beds
Source Rock
Oil
Gas

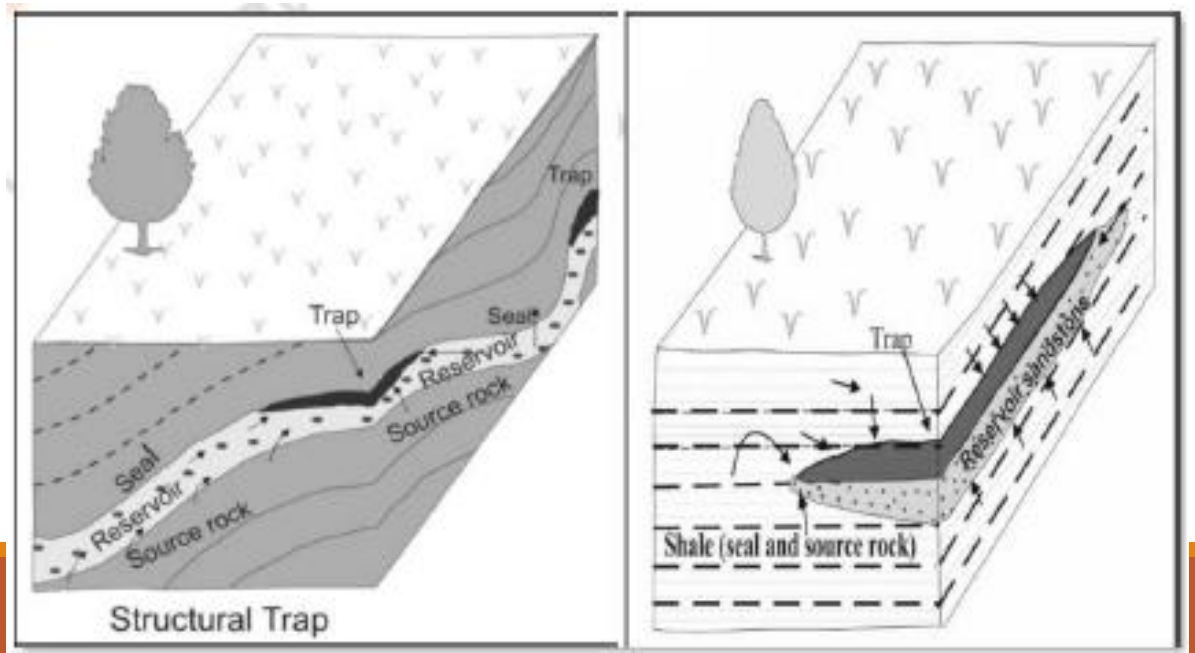
Oil Traps

- When oil migrates from source rock to adjacent porous and permeable reservoir rock it accumulates to form an oil pool covered by an impervious surface, which blocks the further migration of oil.
- There are two conditions necessary for the Formation of oil traps:
  - There should be a suitable structure like fold and faults for oil accumulation.
  - There should be an impervious cap rock, which blocks the vertical and horizontal migration of the oil.
- Once in the reservoir rock, the oil and natural gas continue to migrate through the pore spaces of the reservoir rock until all further movement of the oil and gas are blocked by physical arrangement of the reservoir rock and one or more seals.
- This arrangement of the reservoir and seals is called a trap. There are mainly two types of traps- structural trap and stratigraphic trap.

Oil Traps

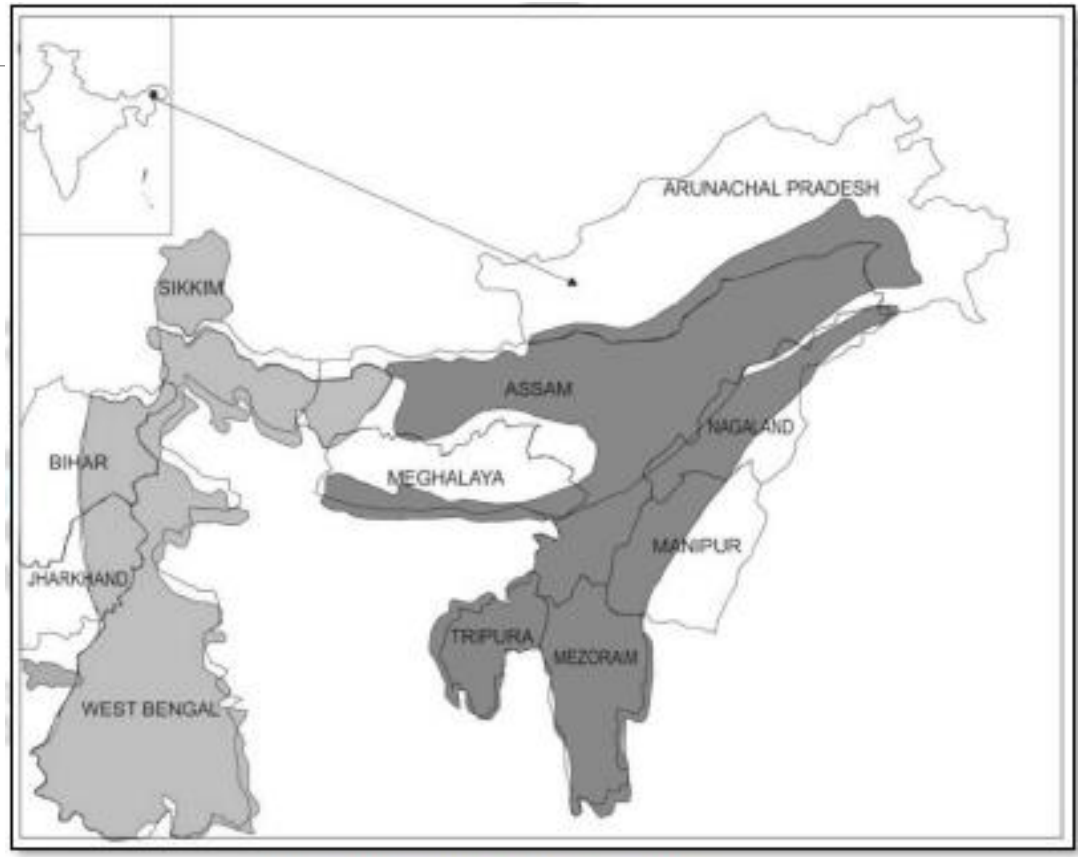
- **Structural Traps-** The structural oil traps are formed as a result of folding, faulting and igneous intrusions. Some of the main types of traps are- Anticlines and domes, Faults, Salt domes and igneous intrusions.

- **Stratigraphic Traps-** The stratigraphic oil traps are formed as a result of lateral and vertical changes in the permeability of the reservoir rocks.These changes are caused by variations in the conditions during the deposition of rocks. Some of the important stratigraphic oil traps are Unconformity traps, sand lenses, wedge outs, etc.



Assam Basin

- The Assam basin is situated in the NE part of India categorized as category-I basin. The basin covers an area of 11, 6000 sq. km.
- Major tectonic elements of basin are: Assam Shelf, Naga Schuppen belt, Assam-Arakan fold belt.
- The oil exploration in India commenced with the discovery of Digboi oil field of Assam. The chief oil fields of Assam are Digboi, Nahorkathiya, Moran, Rudrasagar and Lakwa



Map of Assam- Arakan Basin.

Geology of Assam Basin

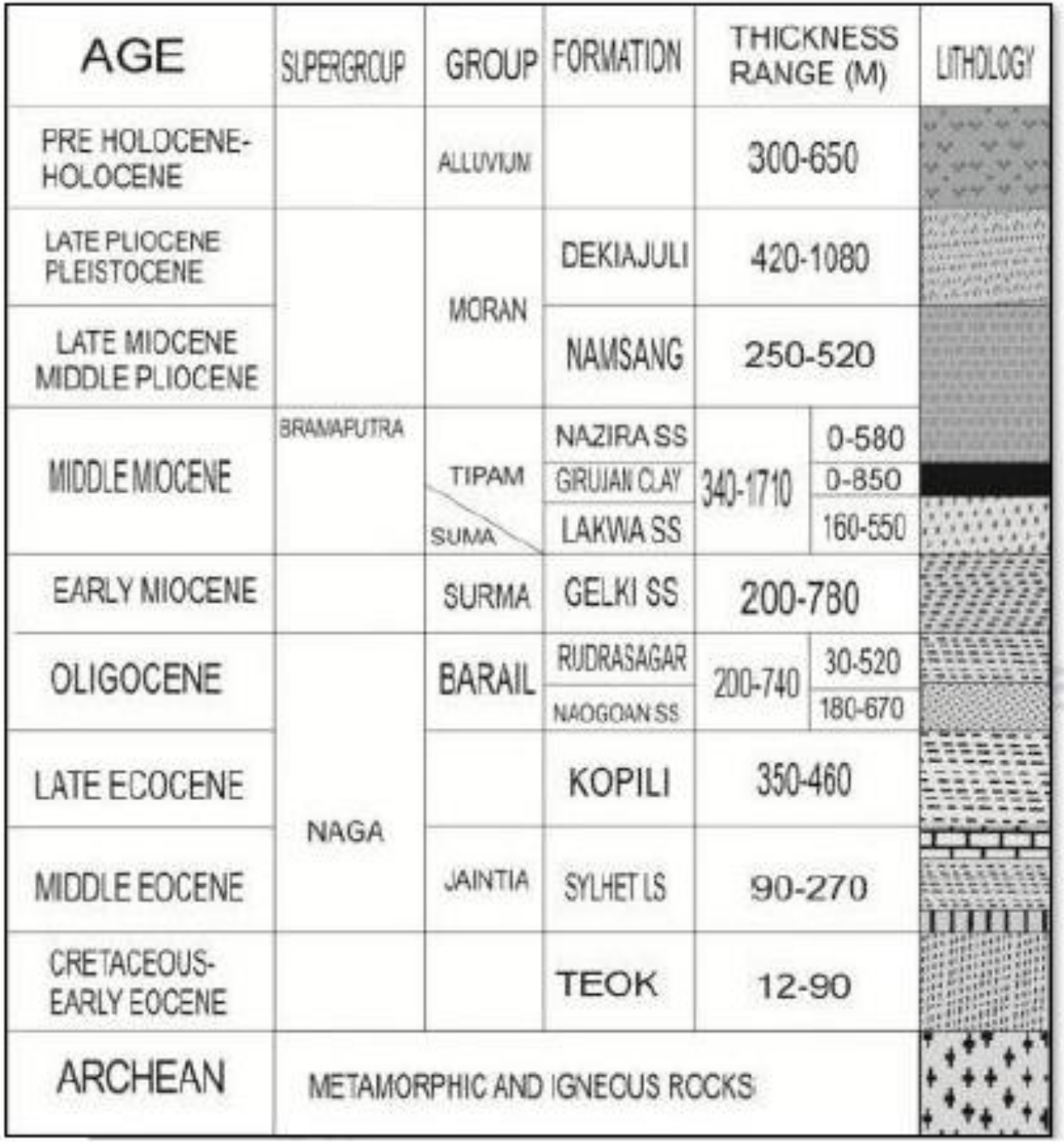
- The basin covers the states of Meghalaya and Assam. The upper Assam basin consists of northern Himalayan foreland basin (HFB) and the southeastern Assam Arakan foreland bas in (AAFB).
- The AAFB consist thick wedge of pre- orogenic passive margin Cretaceous-Eocene (Khasi-Jaintia groups) and deep marine Oligocene (Barail group) flysch sediment overlain by post- Orogenic Neogene molasses (Tipam group). The basement of HFB is covered by the Neogene (Tipam group) and Quaternary.
- The Paleocene to Eocene continental shelf of the Indian plate which became emergent and which is being over-thrust by the Himalayas on the north-northwest and by the Naga hills on the southeast comes under the upper Assam shelf.
- The present-day Assam Basin, a cratonic margin, reflects three distinct tectonic phases. The earliest was Late Cretaceous to Eocene block faulting and development of a southeasterly dipping shelf. Duringthe second phase, in Oligocene time, uplift and erosion occurred north of the many basement faults were reactivated; and many basement-controlled structures became prominent.

Geology of Assam Basin

- In eastern Manipur, thin cretaceous limestones to the south are the oldest rocks reported near the Assam geologic province. The Assam geologic province consist the oldest sedimentary rocks.
- It is comprised of continental to lagoon sandstones and interbedded shales of Upper Cretaceous and Paleocene Dergaon and Disang Formations. The Manipur and Mizoram areas consist more than 5,300m of shales & sandstones and Assam shelf consist more than 500m of sandstones and shales, of the upper Cretaceous and Paleocene Disang Formation.
- The top of the Dergaon and Disang is overlain by the medium-grained massive sandstones of the Paleocene and Eocene Jaintia Group Tura and Langpar Formations and is also marked by an unconformity. In a fluvial to marginal marine environment, more than 250m of the Tura and Langpur were deposited.
- The Eocene Sylhet Formation was deposited in a range of environments and was subdivided into the members which generally represents these different depositional environments. The lower

Geology of Assam Basin

- Lakadong member was deposited in a lagoonal environment consists of more than 350m of thin sandstones and interbedded shales and coals in it basal parts.
- The environment of the Lakadong member typically consists of the thick sands of barrier- bar. The members of upper part of the Lakadong Formation are calcareous sandstone of a restricted shallow water platform.
- The overlying Narputh member consists of claystones and siltstones of a shelf environment. The upper member of the Sylhet, the Prang member, is a shelf carbonate with interbedded siltstones and clay.
- Due to contemporaneous platform tilting and basement sourced block faulting the Sylhet Formation is depositionally thicker from northwest to southeast in the Assam geological province. A 500m of shallow marine to lagoonal shales and interbedded limestones of Eocene Kopili Formation are accumulated over a regional unconformity marked on top of Sylhet Formation



Stratigraphy of Assam Basin.

Petroleum Geology of Assam Basin

- **Source Rock:** Several petroleum systems are present within the Assam Basin geologic province. They have combined the composite petroleum system Sylhet- Kopili/ Barail-Tipam for the assessment purposes.
- For few correlations of source to reservoir where hydrocarbons were available to the time of assessment, a composite Total Petroleum System was used.
- The Total Petroleum System of Sylhet- Kopili/Barail-Tipam are composed of the rocks of the Eocene-Oligocene Jaintia Group Sylhet and Kopili Formations, the Oligocene Barail Group, and the Oligocene-Miocene Surma and Tipam Groups.
- These rocks consist of platform carbonates, shallow marine shales and sandstone, and the sandstone, siltstones, shales and cols of deltaic, alluvial and lagoonal facies.
- **Reservoir Rocks:** In Assam geologic province the reservoir rocks are present throughout the stratigraphic province.

Petroleum Geology of Assam Basin

- Reservoir rock consist of the Eocene-Oligocene Jaintia Group Sylhet Formation limestones and Kopili Formation interbedded sandstones; Tura and Langpar (basal) marine sandstones also have reservoir potential, and Surma Group alluvial sandstone reservoirs are productive in the south -western part of the Assam geologic province.

- The Barail main pay sands and the Tipam group massive sandstones are the most productive reservoirs. Permeability ranges from less than 8 millidarcies to as much as 800 millidarcies in the Tipam Group sandstones with porosities ranging from less than 7 to 30 percent.

- **Migration:** Below the Naga thrust fault, the generation of oil begins by the early to middle Miocene for the Sylhet and Kopili Formations. According to Mathur and others (2001), the onset generation is about 1,750 million years ago for Langpar and Lakadong members of the Sylhet, and today the generation is continuing in the deeper portions of the Assam geologic Province.

Petroleum Geology of Assam Basin

- Primarily the migration is up dip, along the northeast- trending slope of the Assam shelf. The paths of migration may extend to adjacent reservoirs but more often as far as 15 km. the significant volumes of oil found must have migrated from deeper areas along the Naga thrust fault because the source rocks reported in many fields are marginally mature.

- Along the leading edge of the thrust sheet the oil generated beneath the thrust sheet has probably migrated to the leading edge of the thrust sheet and contributes materially to the total oil volume in reservoirs.

- Through reactivated basement-rooted faults associated with plate collision may predominate the vertical migration in some areas, particularly near the edge of Naga thrust fault.

- **Seal and Traps:** The primary traps of area are the anticlines and faulted anticlinal structures, sub-parallel to and associated with the northeast- trending Naga thrust fault. Below the Naga thrust sheet, probably the sub thrust traps are present.

Petroleum Geology of Assam Basin

- There have also been stratigraphic trap discoveries, such as Dholiya gas field, described as an Oligocene Barail clastic depositional lenses, and Hapjan and Sarojani oil fields identified as Barail depositional sandstone lenses.
- The seals of the areas are the interbedded Oligocene and Miocene shales and clays, and the thick clays of the Pliocene Gurjan Group. In the southwestern part of the Assam geologic province, the upper marine shale at the top of the Tipam Sandstone is a regional seal that extends into and throughout much of Bangladesh.

Any Questions??

Thank You !!!