CHAPTER II

Regional Geology of Assam

2.1 Geology of Assam-Arakan Basin

The state of Assam is located near the northeast corner of India between the latitudes of 24° and 28° and longitudes of 90° and 96°. The State covers the plains areas of the Brahmputra and Barak valleys, the Mikir Hills Plateau, the North Cachar Hills, the plains and hill areas of Cachar district and some marginal plateau and hill areas adjoining the neighbouring states. Geologically, the rocks that make up Assam extend in age from very ancient early Proterozoic to the present day Alluvium. Within the Brahmputra valley, the rocks at these extreme ends can be seen at the surface, but much of those of intermediate age are buried under the alluvium.

A Geological map of Assam-Arakan basin is shown in Map 2.1

Map 2.1: Geological Map of Assam Arakan Basin (after OIL’s unpublished report)
2.1.1 Tectonic Evolution

The tectonic evolution of Assam can be understood in the context of cyclic global geotectonic phenomenon – Plate Tectonics and Ocean Floor Spreading. According to Plate Tectonics theory, during a cycle lasting 500 million years or so, the continental masses of the crust fuse together to form one or more super-continents, only to start rifting and breaking apart with ocean floor spreading to keep the breakaway continental fragments moving away from each other. Eventually, the drifting fragments or plates collide with other similar masses in their way and begin forming a new super-continent. Along the line of junction, one plate gets subducted below the other with a lot of sedimentation and mountain building activity at the zone of collision.

At the beginning of the current Plate Tectonic cycle, Assam (together with rest of India, Tibet, Australia, Antarctica, Africa and South America) was part of a super continent called Gondwanaland. The landmass was made up primarily of ancient metamorphics of Archaean to Early Proterozoic age. Around 250 million years ago (Permian) this super-continent started to develop a number of rift valleys. From Late Paleozoic to Early Cretaceous, the Gondwanaland itself started to break up in stages. With Ocean floor spreading in between, large chunks of erstwhile super-continent moved away from mainland with both lateral and rotational movement (Fig. 2.1) (Wandrey, 2004).
Figure 2.1: Gondwanaland during a) Middle Jurassic (166 Ma) and b) Early Cretaceous (130 Ma) (after Wandrey, 2004)

Figure 2.2: Movement of Indian Plate during a) Late Cretaceous (94 Ma) and b) Late Cretaceous (69 Ma) (after Wandrey, 2004)
During this journey, some of the chunks remained large, like Australia, some got fragmented, some joined together with accompanying collision tectonics to former larger landmasses (Fig. 2.2). Eventually, a large chunk of these fragments and composite chunks from north-eastern Gondwanaland collided and fused with the Eurasian plate (Fig. 2.3). The drifting phase started during the Late Jurassic – Early Cretaceous. The collision of the continental masses commenced around Early Eocene and multiple phases of mountain building and mountain-front basin formation has continued since then. The present day basins are reflected by the Brahmaputra, Kopili, Dhansiri and Surma-Barak alluvial plains. Much of the earlier continental crust is buried deep under these basins. Some have been elevated as the Shillong and Mikir Hills Plateaus and their associated hills. Parts of the northern continental margin could have been either subducted or caught up in the faulting and folding activity of Indo-Tibetan collision zone.

In the course of its geological history, Assam has thus passed through five important phases. The first of these relates to when it was a part of Gondwana super-continent. The second phase came in the Permo-Carboniferous, when its adjoining areas were rifted and the coal-bearing Gondwana was deposited. The third phase came in Late Triassic / Early Jurassic when, with the drifting away of Southern Tibet, the northern fringe of India including the part that is now Assam became open to marine sedimentation. The fourth phase started when the eastern boundary also broke apart in Late Jurassic – Early Cretaceous and the southern and eastern shores of Assam became open to marine sedimentation. This phase also saw the beginning of some igneous activity with the outpouring of Garo Hills, Sylhet and Mikir Hills Traps (basalts). The fifth phase started with its collision with Myanmar to the east and Tibet to the north around Early Eocene and continued with all the stages of collision tectonics thereafter. During this phase, the entire land was caught up between two collision zones. The Mishmi Hills added a third compressional force from the northeast and subsequently a major uplift of Shillong-Mikir Hills Plateau also contributed.
2.2 Stratigraphy of Assam-Arakan Basin

2.2.1 Basement Complex

The basement complex is a crustal fragment of the ancient Gondwanaland, made up of metamorphosed igneous rocks and the sediments of the Archaean to Early Proterozoic age, with some embedded less metamorphosed sediments of younger Proterozoic to Early Cambrian age. The basement complex is tilted towards the north, northeast and east. The continental part of the Indian plate came close to Tibetan and Myanmar plates by Early Eocene, but the oceanic extension of the Indian plate collided and started their subduction process well before this time resulting in the development of a tilt or slope of the Basement towards the collision zone where mountain building and basin formation started.

2.2.2 Mesozoic-Cenozoic Stratigraphy

The South Tibetan Plate fragment of Gondwanaland became detached from the India part around Late Triassic or Early Jurassic, permitting some sedimentation to commence at the northern fringe of the Indian plate. India’s detachment from Antarctica and Australia occurred around Late Jurassic – Early Cretaceous. Sedimentation on its fringe could have started at this time, but a period of
igneous activity intervened leading to formation of Rajmahal, Sylhet and other related basaltic lava flows (Traps) and intrusives. Therefore, sedimentation started some time later.

Basinwards, the shelf slopes down to a prominent hinge zone, beyond which the entire Cretaceous-Eocene section turns into a thick group of indurated shales with some sandstones and occasional thin bands of fossiliferous limestones, known as the Disangs. The Disang Fault or Thrust demarcates the position of the hinge up to approximately the longitude of 92° 20’ E. Within Assam, Disangs have a very restricted presence and are confined to a narrow belt to the south and east of Disang thrust in North Cachar.

As the South Tibet and Myanmar Plate fragments broke apart from the Gondwanaland from about Late Triassic to Early Jurassic, there was ocean floor spreading between these and India leading to the formation of large ocean floor extensions in the corresponding parts of India and these plate fragments. As the South Tibet and Myanmar Plate fragments joined up with Eurasia around Mid-Cretaceous and India continued to close the gap, the oceanic extension of the India Plate started to get consumed through subduction. This was accompanied by basin formation and compressional tectonics in the collision zone.

2.2.3 Palaeogene Stratigraphy

At around Mid-Cretaceous, when the collision between the oceanic extensions of India Plate with those of its neighbours first started, the sediments of the shelf areas and the collision zone were several thousand kilometres apart. But as the continental part of India closed in, the gap slowly decreased, so that by Late Eocene the shelf and the peripheral tectonic basins had come reasonably close to each other. The configuration of the colliding Indian and Myanmar continental masses were such that collision started at the north-eastern end and progressively extended southwards.

In the northern outcrops of Sylhet and Cachar, Eocene Kopilis were overlain conformably by a thick group of sandstone and shales which formed the Barail Range of the area. They were accordingly given the name of Barails and the Barail Range became its type area. Similarly local names were given based on
the lithological associations. For example, a sandstone-shale sequence named Bhubans from the Bhuban Hills to the southeast of Silchar’s Cachar, a shaly sequence named Boka Bils from their association with a muddy lake on the west flank of Masimpur anticline in Cachar, a sequence of massive sandstone named Tipams after the low Tipam range and the Tipam river in northeast Assam and a sequence of mottled clays and sands named after Giru Jan to the east of Digboi.

2.3 Geology of the Study Area

The study area is confined to the shelf zone, which is structurally less complex and tectonically less disturbed compared to the thrust zones to the southeast. The tertiary sediments in the shelf zone of the basin are considerably thick, ranging from 3.6 to more than 7 km, and include shallow marine Paleogene and continental Neogene sediments overlying a granitic basement. The generalized stratigraphic section of the Upper Assam shelf region and a geologic cross section across the study area are shown in Figures 2.4 and 2.5, respectively (Mathur et al., 2001). Tectonically, the Upper Assam basin represents a structurally warped foreland basin between two convergent margins. During a major part of the Cretaceous and early Paleogene, the shelf zone of the Upper Assam basin was situated on a passive continental margin having a depositional environment that was predominantly near-shore to shallow marine. This depositional environment prevailed during the early and middle Eocene. The shelf zone experienced a change in the depositional setting to a deltaic-estuarine condition during the latter part of the Eocene and Oligocene, followed by a fluvial phase in the Miocene and younger times.
Figure 2.4: Stratigraphy of the study area (after Mathur et al., 2001)
2.4 The Petroleum System

The upper part of the Langpar formation and the lower part of the Lakadong member of Sylhet Formation contain rich source rocks in the form of carbonaceous shale and coal and are commonly interbedded with clastic reservoir rocks and nonsource shales. Geochemical studies carried out on the source rocks and crude oils in the Upper Assam basin have indicated predominantly type II and III organic matter (OM) and significant input of terrestrial OM (Raju and Mathur, 1995). These source rocks are in the early mature stage (beginning of oil window) in the area close to the oil fields. In the deeper part of the basin toward the south and southeast, however, they have attained sufficient maturity for peak oil generation, as indicated by modeling studies. The burial history and thermal maturity reconstructions for the Eocene source rocks indicate that the critical moment (onset of oil generation) probably commenced during the upper Miocene in the areas just north of the Naga thrust belt. The trap formation is believed to have occurred during the lower Miocene and later been modified during the upper Miocene. In the absence of definitive evidence, such as detailed carbon isotope and biomarker data, however, the level of certainty of the Langpar-Lakadong system can, at this stage, be qualified as hypothetical [(.)].
Figure 2.6: Petroleum system active in the study area (after Mathur et al., 2001)
The major oil and gas reserves are mainly confined to the Lakadong member of the Sylhet Formation and Langpar Formation. The sandstone reservoir units are broadly grouped into three possible genetic types based on their lithological and reservoir characteristics, thickness variation, and vertical distribution (Fig. 2.7). Of these, the thin sand group occurs as thin (< 2 m) sandstone units in the lower part of the Lakadong member. These sands are characterized by moderate to low permeability and are commonly poor producers. The presence of mudstone, silt, and coal above and below the sand units and the poor lateral continuity of the latter indicate deposition in a tidal flat/marshy/lagoonal regime. The organic rich lagoonal shale/coal units are the major Eocene source rocks in the basin.

The thick sand group occurs as thick (2–6 m), clean, porous and permeable sandstone within the middle part of the Lakadong member. These highly productive sandstone bodies, characterized by a funnel-shaped gamma-ray/spontaneous potential (SP) and resistivity log pattern that has gradational basal contact and sharp top, were probably deposited in a prograding sand-rich strand plain/barrier bar system. The smooth cylindrical gamma-ray/SP and resistivity log pattern in the upper section of some of the sandstone units and moderate dip scatter indicate high energy deposition having strongly directed currents. The heterogeneous sand group occurs as highly heterogeneous calcareous sandstone within the upper part of the Lakadong member. The presence of hydrocarbons has been established from wire-line log evidence and drilling, but only a few sands have been tested, owing to the generally poor reservoir characteristics. The lithologic association of this unit coupled with low to moderate dip scatter indicate deposition in a shallow-water neritic environment. The thick sequences of shales within the Kopili, Prang, and Narpuh, having a combined thickness of about 800 m, are believed to provide the regional seal for the hydrocarbons. Locally, however, the presence of faults cutting across these formations might have aided tertiary migration into younger reservoirs (Mathur et al., 2001).
Figure 2.7: Representative E-log section from a well in the study area indicating depositional environment, lithological characteristics and hydrocarbon distribution with the Eocene sequence (after Mathur et al., 2001)