Chapter 1

Introduction

1.1 Statement of the problem

The Upper Assam Basin is a significant onshore petroleum province in India, producing oil and gas and has been a productive hydrocarbon producer for over a century since oil was first discovered in Digboi, Upper Assam in 1889. Two state owned companies OIL (Oil India Limited) and ONGCL (Oil and Natural Gas Corporation Limited) involved in petroleum exploration and exploitation from Upper Assam sedimentary basin. Early investigation for oil in this basin has been carried out during 1950-1980 and resulted a number of large discoveries in Oligocene-Miocene fluvio-deltaic reservoir. A thoughtful search for hydrocarbon prospects in detail (Late Paleocene-Early Eocene) was initiated by ONGC in the year 1985. The presence of hydrocarbon in the deeper horizon (Eocene sandstone reservoir) in the basin has been initiated for the first time with the drilling of a well in the Lakwa field. Simultaneously, exploration of petroleum was more profound prospect in Late Paleocene-Early Eocene sequence to the North-East of ONGC acreage after the set up of different medium sized oil fields like Dikom, Kathalani, Tengakhat, etc., in the Barail Group.

The Upper Assam Basin is a composite foreland basin. The sedimentation process in the basin was formed during passive margin setting in Paleogene time during drifting phase of Indian Plate after detachment from Antarctica Plate. In the Paleocene to lower Eocene period, fluvial to marine clastic sediments were deposited in the basin after widespread transgression leading to deposition of carbonate sediments in middle Eocene period and shale is dominated in upper Eocene time. A higher proportion of coarse clastic sediments are attributed to the tectonic uplifts during Oligocene and Miocene in the origin and also falling sea level. During the late Miocene to Pliocene Period, a successive basin wide compressive orogenic phase accumulate resulting emergence of landforms and subsequent erosion are marked by unconformity between Tipams and overlying sediment formation.
From Paleocene-Eocene to Recent age, the sand and shale alterations of the sediments primarily comprise the geologic formations in the basin.

Carbonaceous shales and coals of the Barail Group of rock have been long regarded as an important source rock horizon of Barail-Tipam petroleum system in the subsurface of Upper Assam. However, routine studies of the carbonaceous rocks of the Barail Group by the oil companies point to presence of immature organic matters in them (Pahari et al., 2008). In this context, a detail and holistic study of the sub-surface organic matters of the Barail Group of Upper Assam using both organic geochemical and petrographic analyses is considered as very important to identify the source rock horizon and petroleum potential of the Barail-Tipam petroleum system of the Upper Assam Shelf. Works on similar line, like those of Misra (1990), Gogoi et al. (2008) etc. are mostly based on the outcrop samples. The present work aims at detailed study of organic geochemistry and petrography of the carbonaceous shales and coals of the Barail Group of rocks of the Upper Assam Shelf for characterization of source rock potential, thermal maturity and depositional environment based on the samples collected from the exploratory wells of the ONGCL.

1.2 Location of the area

The study area from where the core samples of carbonaceous shale and coal were collected belongs to the oilfields of Upper Assam Shelf represent the operational areas of ONGCL’s jurisdiction. The oilfields present in and around Sivasagar District whose exact location (latitude and longitude) has not been displayed due to official obligation and as per the guidelines of the management of ONGCL. The locations and generalized geological map of the study area are shown in Figure 1.1.

1.3 Accessibility

The oilfields from which the samples are collected are well connected with the rest of the country by highways, railway tracks and air routes. The region is at a distance of about 350km from Guwahati along the Assam Highway No.1. Oilfields are well connected by railway tracks too and the nearest important railway stations are Sivasagar, Simaluguri and Amguri. The nearest airport is located at Jorhat at a distance of about 65km.
1.4 Geomorphology

The Upper Assam Shelf signifies the north-eastern extremity of the Indian subcontinent with 57000 sq. km. area which represent a part of the north-eastern Assam-Arakan geological province. The basin is bounded in the NW by the Eastern Himalayas and in the SE by the Naga-Patkai Hill Ranges whereas Mishimi and Mikir Hill massifs hills form the NE and SW boundaries respectively.

The topography of Upper Assam Shelf is characterized by a vast alluvial plain formed through the Quaternary Period by the Brahmaputra River and its tributaries. The elevation of the valley is highest along the boundary of the Mishimi Massif that ranges about 300m to 250m. The highest elevation is seen along the flank of the Manabhum range at the south-eastern corner of the valley. The elevation gradually decreases towards the west along the Brahmaputra River. Near Bokakhat town, which is situated...
at the western flank of the Karbi-Anglong plateau, the general elevation is around 80m above the MSL.

The tributaries on the northern and southern banks of the Brahmaputra River display contrasting characters. The south bank tributaries originates in the Naga-Patkai Hill ranges and flow along meandering courses across a nearly leveled plain with a low northerly gradient. The south bank tributaries do not carry much sediments in comparison to their northern counterparts. Important southern tributaries are the Lohit, Burhi Dihing, Disang, Dikhow, Jhanji and Dhaniri.

The northern tributaries originate in the eastern Himalaya and follow braided course and characterized by high water and sediment discharge. These tributaries flow across the northern flood plain of the Brahmaputra River with a southerly trend and cause very frequent flash floods and bank erosions during the monsoon season. Important northbank tributaries of the Brahmaputra are Subansiri, Jia Bharali, and Dikrang etc.

1.5 Objectives

The objectives of the present work are:

1. Determination of richness, types and maturity of organic matters based on both organic geochemical and organic petrographical methods
3. Study of depositional environment based on different geochemical and petrographical analysis.

1.6 Literature review

The study area is located in the Upper Assam Shelf, which belongs to the northeastern part of Indian subcontinent. Earliest understanding of the geology of the Upper Assam Shelf have been made by the geologists of the Geological Survey of India, Burma Oil Company, Assam Oil Company, Oil India Ltd. and Oil and Natural Gas Commission (Presently, Oil and Natural Gas Corporation Ltd).

The initial systematic geological investigation in the Assam-Arakan Basin has been carried out by during Geological Survey of India in middle of the last century which was followed Burma Oil Company and Assam Oil Company, initiated detail
survey in this sedimentary basin. An extensive reconnaissance survey has been made in the exposed part of Naga Hills and adjoining areas by Mallet (1876), suggested the stratigraphic classification for the area and classifying the Cenozoic Sediments of the Upper Assam Shelf in four series within Tertiaries i.e. Disang, Coal Measures, Tipam and Dihing.

The pioneering work in the field of geology was done by Medlicott (1865) and Mallet (1876) and their studies reported the geological mapping of Upper Assam. The premier Assam Oil Company which was established in 1912 at Digboi in Upper Assam also gives significant geological contribution regarding Upper Assam Basin. Extensive prospecting for oil was carried out by this company during that period.

The Geological Survey of India during the pre and post Independence era has been subsequently carrying out geological investigations and appraisals of mineral occurrence in different parts of Assam.

After (Mallet, 1876), geological mapping and traverses in parts of Upper Assam were followed up by La Touche (1886), McLaren (1904), Brown (1912), Pascoe (1912), Murray (1923), Banerjee (1951), Goswami (1960) etc.

Generally, the concept based on the lithostratigraphic status for the Eocene sequence was favoured by most workers as it was established that on the basis of gross lithologic characters, heavy mineral zones, electric and other log properties, the entire sequence can further be divided into distinct groups, formations and members.

Evans (1932, 1958) worked out the first comprehensive stratigraphy of the Assam Arakan Basin and classified the Cenozoic sequence of Assam in a detailed manner and suggested a detailed stratigraphic framework for successions of Naga Hill, Barail Range, Surma Valley and South Shillong Plateau. Later, Mathur and Evans (1964) proposed another classification for both the shelf and basinal part of Assam-Arakan keeping the same time stratigraphic (series) nomenclature and classified the Tertiary sequence of NE region into a Shelf and a Geosynclinal facies. However, they opined that the designation of stratigraphic unit like “stages” and “sub stages” would appear to be equivalent to Group”, “Formation”, and “Member”.

Based on the of Evans (1932) classification, various workers reported many schemes of classification with introduction of new stratigraphic sequences and regrouping the various litho 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.

Biswas (1961) of the Standard Vacuum Oil Company preferred to use the rock stratigraphic nomenclature to the succession of Assam based on stratigraphy and micropaleontology.

Bhandari et al. (1973) proposed the first comprehensive subsurface lithostratigraphy of Upper Assam and subdivided the Tertiary sediments into Naga and Brahmaputra Supergroups separated by a major Oligocene unconformity. Based on American code of Stratigraphic Nomenclature (1961), this Supergroups are further subdivided into groups and formations. In most of the parts of Upper Assam, the OIL has carried out the geological mapping and suggest a stratigraphic succession in the area under Oil’s jurisdiction.

Ranga Rao (1983) carried out a detailed compilation of geology of Assam-Arakan Basin and its adjoining areas. Dasgupta (1977), Samanta (1965, 1969 and 1971), carried out detailed biostratigraphy of the outcrop of Assam-Arakan Basin. The Palaeogene biostratigraphy of the subsurface of Upper Assam has been studied by Mohan and Pandey (1973), and Singh et al. (1986).

Shrivastava et al. (1974), Baruah and Ratnam (1982), Sinha et al. (1982), Dutta (1982), Singh (1986), Handique et al. (1989), have also described the Cenozoic sediments of the Upper Assam Shelf. Many geologists have used different terminology for the same horizon and as a result new names have been introduced for the different groups, formations and members.

Significant contributions to the stratigraphy and tectonics of the Upper Assam shelf areas and Meghalaya have been reported by Evans (1964); Wilson and Mitre (1953); Metre (1968); Chakraborty (1971); Chakraborty and Baksi (1972); the stratigraphy and geological evolution of the basin by Raju (1968); Goswami (1960b, 1964); Sah and Dutta (1966); Dutta (1993).

A review report based on Lithostratigraphy of the Shelf Sediments of Paleogene period has been given by Sarmah and Borgohain (2012), studied the detail classification and nomenclature, lithostratigraphy of Paleogene Shelf Sediments in Assam and Meghalaya. More recently, Dasgupta and Biswas (2000) has been published in a book.
reported summarized account on “Geology of Assam” which may consider a significant and valuable contribution to the geo scientific work on the Tertiary sequence of Upper Assam as well as the North East India.

Wandrey (1994) studied the Sylhet-Kopili/Barail-Tipam composite Total Petroleum System, Assam Geologic Province, India and reported that Sylhet and Kopili Formation shales, Barail Group coals and shales, and in the south the Surma Group shales as source rocks for hydrocarbon generation. This study also reported that the maturities are generally low; increases to the SE near the Naga thrust fault and in the subthrust zone, the maturity can be expected as higher. Generation began in early Pliocene and the migration is generally from updip along the northeast-trending slope of the Assam Shelf, and vertical migration occurs through basement-rooted faults which is associated with the plate collisions.

A comprehensive classification of Indian Sedimentary Basins using the Dickinson (1976) scheme, Biswas et al. (1993) for the first time published of Basin classification based on the structural style, geometry and size, nature of stratigraphic fill and thermal history into 38 sedimentary Basins. This classification grouped the sedimentary basins in three main settings: (i) intracratonic, (ii) rifted, (iii) orogenic settings and based on the hydrocarbon proclivity, these basins were regrouped into 26 sedimentary Basins.

Mallick et al. (1997) has reviewed the works on evaluation of the formations, log responses, geochemical characteristics, depositional environments of the source rock and reservoir rock, and problem and challenges related to Eocene reservoirs from parts of the Upper Assam basin.

A detail study have been carried out on oil prospects of Assam Shelf and its adjoining parts by Murty (1983); Ranga Rao (1983); Desikachar (1984); Rao (1987); Handique (1993).

Kunte (1988) have been carried out the geomorphic analysis of Upper Assam Plains and adjoining areas for hydrocarbon exploration. His study include Terrain Analysis of the Assam Plains and adjoining areas of the Naga foothills and Mikir hills plateau by using LANDSAT images and cartographic maps, essentially as an aid for planning seismic surveys for hydrocarbon exploration.
Carbonaceous shales and coals of the Barail Group of rock have been long regarded as the important source rock horizon of the Barail-Tipam petroleum system in the subsurface of the Upper Assam region. However, a detailed study of their organic geochemical characteristics has not been conducted. Some authors reported limited information, mostly based on the outcrop samples, which may not have direct bearing on oil generation in the subsurface of the Upper Assam Shelf (Misra, 1990; Gogoi et al., 2008).

Source rock potential of organic matter rich shales in the tertiary Bhuban and BokaBil formation has been carried out by using standard organic geochemical and organic petrographic techniques (Farhaduzzaman et al., 2012a). The authors have suggested that the shale analysis can be reported the source rock as poor to fair gas-prone and geochemical parameters supports a maturity range from just pre-oil window to mild-oil window.

Oil and gas generating potential of Barail shales of Upper Assam Basin, their prospects as an oil shale or shale oil resource have been studied by Mathur and Raju (2014). This study is based on analysis both surface and subsurface samples from the thrust belt area of Upper Assam and Rock Eval and Pyrolysis Gas Chromatograph Mass Spectrometer (Py-GC-MS) are used to determine the hydrocarbon distribution.

Sahoo and Gogoi (2011) studied the structural and sedimentary evolution of Upper Assam Basin, India and implications on hydrocarbon prospectivity and the study demonstrates that the migration of basin bounding fault has profound controls on development of potential plays in the basin. The study also reported that the expulsion of hydrocarbon is considered to be more efficient in the belt of Schuppen and the number of fault conduits is developed to bring the hydrocarbon charge to shallow reservoirs. The migration is primarily up dip to the northwest along the northeast-trending slope of the shelf, with vertical migration occurring through reactivated basement-rooted faults associated with the plate collision.

Singh et al. (2011) studied the Gondwana Sediments and their hydrocarbon prospects in Dhansiri Valley, Assam and Assam Arakan Basin – India and suggest that the significant amount of commercial hydrocarbon as well as gas production in Dhansiri Valley are from Tertiary and Pre-Tertiary reservoirs.
Geochemical characterization of source rock from the North Bank area, Upper Assam Basin has been carried out by Devi et al. (2017). In this study, authors have reported the systematic study of the source rock potential by using Rock-Eval pyrolysis combined with a GC and TLC-FID to characterize the source rocks, their distribution and thermal maturity of the organic matter. The work reveals that the hydrocarbon generation potential of the studied rock is constrained by low maturity.

From the above survey it is seen that different geochemical and organic petrographic study has been used for evaluation of hydrocarbon prospects of different geological area, but very limited research work has been carried out by using well core samples of different exploratory wells of Upper Assam oilfields.

1.7 Overview of the Thesis

This thesis continues with the following chapters:

**Chapter 1: Introduction**: This chapter introduces statement of the problem of the present work which aims at characterization of hydrocarbon source rock potential, thermal maturity and deposition environment of Barail Group of rocks in the Upper Assam Shelf based on organic geochemical and petrographic study of sub surface samples. This chapter introduces the location, accessibility, geomorphology etc. of the study area and also the objectives related to this study. This chapter also includes the literature review relating to the present study.

**Chapter 2: Geology of the area**: This chapter mainly focuses on the geological settings of the study area. This chapter includes the evolutionary history of the area and also the structure and the tectonics as a whole.

**Chapter 3: Material and Methods**: This chapter presents sampling method as well as the area of sampling in detail. The methodology for geochemical analyses, organic petrographic study and also the biomarker analyses are explained in this chapter respectively. The details of the instruments used for different analysis are presented in this chapter.

**Chapter 4: Physico-Chemical Analysis**: This chapter includes the proximate and elemental analysis of the studied samples. In this chapter detail characterization of the Barail coal and carbonaceous shale horizon have been done. Elemental analyses includes the presence of different constituents like C, H, N, O, TS etc. which are helpful
to study and characterization of the samples. A statistical analysis has also been performed to see the similarities among the sample units as well as the oilfields.

**Chapter 5: Rock Eval Pyrolysis:** This chapter involves the pyrolysis data of the samples of different well which contain the basic parameters- $S_1$, $S_2$, TOC, $T_{\text{max}}$, OI and HI. These parameters help to interpret and to evaluate the hydrocarbon generating potential, thermal maturity and also the depositional environments of the Barail Group of rock under study. This chapter has been published in an International Journal (Sharma et al., 2016). Furthermore, to see the similarities among the parameters viz., $S_1$, $S_2$, TOC, $T_{\text{max}}$, OI and HI, a statistical analysis has also been performed.

**Chapter 6: Biomarker analysis:** This chapter includes the study of coal and carbonaceous shale samples which extracted with organic solvents for GC & GC-MS analyses to identify the biomarkers. Biomarker analyses help to study and interpret the source rock potential, thermal maturity and environment of depositional conditions of the Barail group of rock under study.

**Chapter 7: Organic petrography:** In this chapter organic petrographical analyses have been reported which help to study the hydrocarbon generation potential and also characterize the depositional environment of the study area.

**Chapter 8: Conclusions:** This chapter presents the summary and conclusions drawn from the present work.