

Deciphering Hydrocarbon Migration Pathways in Upper Assam South Shelf Amanjot Kaur*, Sundar Raman and Binita Mandal

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Keywords

Upper Assam South Shelf, Petroleum System Modeling, source rocks, source rock kinetics, maturity, transformation ratio, migration pathways

Abstract

Predicting the present by modeling the past is a powerful tool for oil and gas industry and Petroleum System Modeling studies provide inkling to the elements and processes controlling hydrocarbon accumulations. The present modeling study pertains to southern part of Assam shelf also known as Upper Assam South Shelf (UAS). The UAS has reservoirs from Basement to Tipam and the exploration is in mature stage but exploration surprises and new play corridors keep opening. The existence of Petroleum System in the basin is a foregone conclusion but to mitigate exploration risk, the elements and processes need to be understood. It is documented that source rocks on the Assam shelf are not mature and it is assumed that mature source rocks are present below the Schuppen Belt. However, presences of organic rich source rocks in a few wells in the UAS, capable of generating of hydrocarbons have made it possible to model migration pathways. The generated and expelled volumes are low but it still depicts a fill-spill pattern of reservoir filling at multiple levels with faults having impact on hydrocarbon migration and accumulation. The analysis has brought out the charge risk in the study area and will help in mitigating exploration risk in future.

Introduction

The Upper Assam Shelf South block (UAS) falls in the southern part of Assam shelf, which has evolved as a polycyclic basin. The Brahmaputra River defines its northern, Mikir massif western and south-western and NE-SW trending Naga Schuppen belt eastern boundaries respectively (Figure1). East west trending dextral wrench Jorhat fault separates the study area from the North Assam Shelf. The present study area has hydrocarbon finds like Borholla, Khoraghat, Nambar, Suphayam, Dayalpur, Uriamghat and Kasmarigaon structures. Study area extends from

Borholla field in the north to south of Nambar field an aerial extent of more than 800 skm.

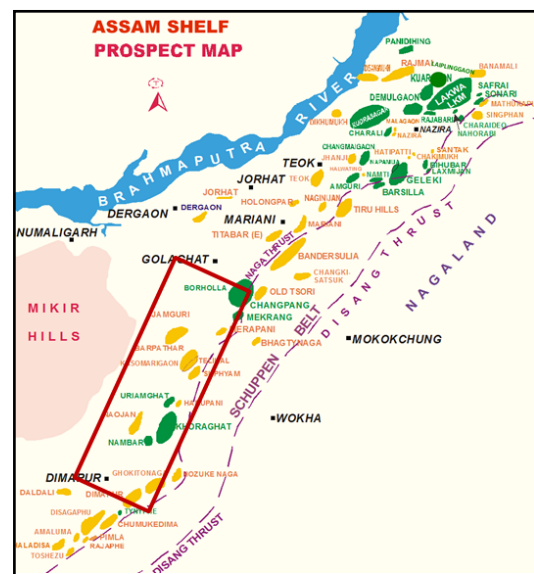
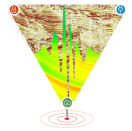


Fig1: Map showing the study area

Tectonics, Geology and Stratigraphy: Assam and Assam Arakan basin has poly-phase tectonic and depositional history. The study area is criss-crossed by NNE-SSW trending major normal fault system down to the Basement.

The initial basin formation in the Assam Shelf is considered to have begun in the Permo-Triassic with the development of a number of grabens filled up with the Gondwana sediments, trap and Early Cretaceous rift fill. The rift fill sediments have limited extent on the shelf. The shelf hosts passive margin sediments of Late Cretaceous to Oligocene age and foredeep sediments of Miocene to Recent age with Granitic gneiss as basement. The passive margin sequence of Late Cretaceous to Oligocene overlies either rift fill sediments or on the basement



directly on the shelf. These sediments are followed by foredeep sediments of Miocene to Recent age. The Tura, Sylhet, Kopili and Barails belong to the former and the Tipam Group belongs to the latter. The Tura Formation (Paleocene to Early Eocene), is composed of sandstone with a few shale bands. The Sylhet Formation is represented by limestone and sandstone alternations of Middle-Eocene age. The Kopili Formation is dominantly argillaceous with a few limestone intercalations towards the bottom and a few sand lenses. The Barail Group (Late Eocene to Oligocene), is dominantly arenaceous, but is argillaceous towards the bottom. The Bokabil Formation developed in Upper Assam South is composed of lower sandy unit, a middle shaly unit and an upper sandy unit which gradually merges into the overlying Tipam Group north of the Borholla structure. The Tipam is undifferentiated in the South Assam shelf (Figure2).

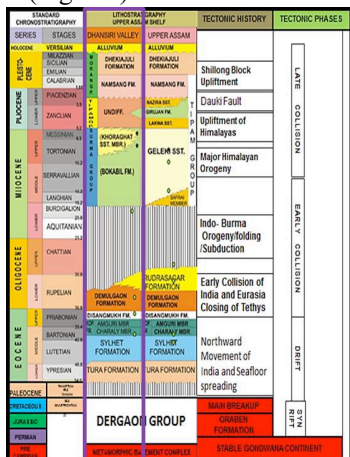


Figure2: Stratigraphy of Assam Shelf (Source :Lithostratphy document X,1993)

Petroleum System Modeling:The primary aim of the petroleum system modeling study is to get a better understanding of the petroleum systems in the South Assam Shelf and attempts to build an understanding of possible migration pathways from source to reservoir and further explore the prospectivity of established plays in the area as well as understand migration pathways A petroleum system includes elements such as effective source rock, reservoir rock, seal and overburden rock and the geologic processes include trap formation and generation, migration and accumulation of petroleum.

A petroleum system exists whenever the essential elements and processes occur.

Source Rocks: The geochemical data of 50 exploratory wells have been analysed for organic matter richness (TOC, wt. %), source potential (S₂, mg HC/g rock), type of organic matter, thermal maturity (VR_o, Tmax) and thickness of source rock. The limited data indicates few potential source rocks sequence in rift fill having limited extent with TOC 1.75-2.91% and HI 101-247 mgHC/gTOC. The principal source rocks are developed in passive margin sequence. The Sylhet possess fair to good organic richness (TOC 1.38-6%,HI of 82-250 mg/Hc/g TOC), Kopili sediments also possess fair to excellent source rock characteristics(TOC 1.7-7.3%,HI of 89-220 mg/Hc/g TOC & S₂ 2.94-15.38 mg/Hc/g rock). The Oligocene Barail sediments within passive margin are found to be highly organic rich among all the sequences. The HI values indicate mainly Type III organic matter. However cross-plots of HI vs. Tmax, the modified Van Krevlen diagram depict type III + II organic matter in the UAS (Figure 3).

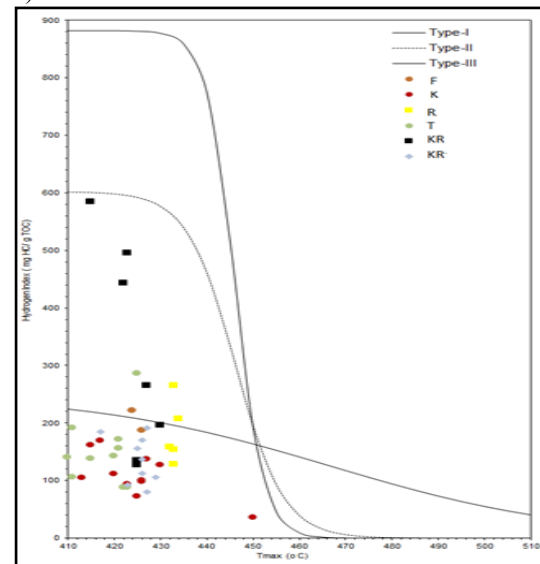
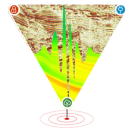


Figure 3: Modified Van Krevlen diagram of UAS

The conventional maturity parameters like vitrinite reflectance (VR_o), Tmax, biomarker ratios and production index (PI) values in shelf area indicate that the source rocks are mostly immature. However early oil maturity is observed (VR_o 0.6%) in a few areas within UAS, and the pre Barail source rocks are



immature to marginally mature in most of the frontal area of Naga thrust. The Tmax values are lower than 440°C and the occasionally vitrinite reflectance values greater than 0.6 are reported. The most mature Eocene samples are located close to the Naga Thrust. In Late Eocene (Kopili) source sequences, early oil generation maturity is observed and Sylhet in upto 0.68 & 0.73% VRo in in south eastern part of study area near Naga Schuppen zone. The entire modeled area falls within Immature to Early Oil window as observed in the maturity data. This has given rise to the premise that mature shales within Sylhet, Kopili and Barail formations below Naga Schuppen belt are the source for hydrocarbons in the Assam shelf. The 2D petroleum studies connecting Shelf to Schuppen belt indicate modeled source rocks below Schuppen attain sufficient maturity and transformation for effective migration and accumulation to take place on the shelf. These studies give credence to the proposition that effective source rocks and mature source pods/kitchens lie below Schuppen in the subthrust. The Rock Eval analysis of organic matter suggest certain source intervals have Tmax 432-430°C and which early generating kinetics and have significant amount of type II organic matter/liptinitic organic matter.

Reservoir Rock: Main reservoirs are fractured Granitic Basement, sands/limestone of Sylhet, sands of Kopili, Barail, Mid Bokabil/Bokabil formations and fluvial sands of Tipam Group.

Traps: The entrapment is dominantly structural mainly four-way closures / fault closures in Sylhet, Kopili, Mid Bokabil and Bokabil. Besides the structural entrapment fracture network in basement provides suitable entrapment in Borholla, Changpang, Khoraghat and Dayalpur area.

Seals: Intra-formational shales within Sylhet and Kopili, remnant coal-shale unit in Barail and Bokabil shales act as seal for their respective Mid Bokabil pays.

The 3D petroleum system modeling was carried out on PetroMod platform to evaluate generation of charge, migration and entrapment of hydrocarbons in the study area. The modeling includes several dynamic processes, including sediment deposition, faulting, burial, kerogen maturation kinetics and multi-phase fluid flow. The initial 3D geological model in PetroMod was built, using the key stratigraphic level depth surface, fault geometries, facies maps, geochemical data and timing of deposition,

hiatus & erosion and boundary conditions Figure 4. The maturity and transformation of organic matter are the two parameters which help evaluate generation potential of the source rocks. Different kinetics were used in the study for building, modeling & visualizing multiple migration scenarios with basinal kinetics, custom Early generating kinetics, default kinetics available in PetroMod (Burnham TIII, Pepper Corvi TIII) .

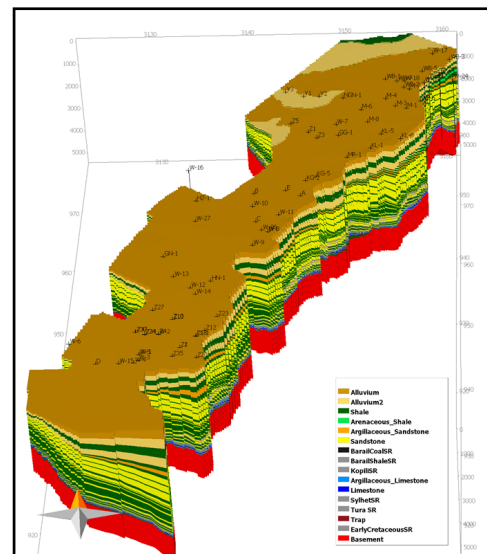
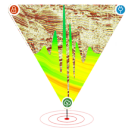


Figure 4: Final Model Geometry

The scenarios were tested on quality and stratigraphic distribution of source rocks, kinetics and by defining properties to some selected faults to understand their impact on migration and hydrocarbon charge. The results of some of the scenarios are discussed below:

Scenario-I Basinal and Default Kinetics: The general maturity overlay from modeling shows that the different maturity source rock levels i.e. Sylhet, Kopili and lower part of Barails occupy only initiation of early oil generation maturity window that too confined to very limited area. Rock maturity of the model clearly depicts that the entire area is ranging from immature to early oil window maturity (Figure 5). Deeper source layers within Tura, Sylhet, Kopili are well within the Early oil window in the deeper portions of the modeled area whereas Barail source layers only show a few within the Early oil window. The rest of the layers Miocene onwards are immature. The present low geothermal gradient observed in the



wells is due to the collision and subsequent subduction of Indian plate post Miocene leading to much colder thermal regime. The transformation ratio overlay for the source rock layers modeled with custom kinetics indicate negligible transformation in the modeled area.

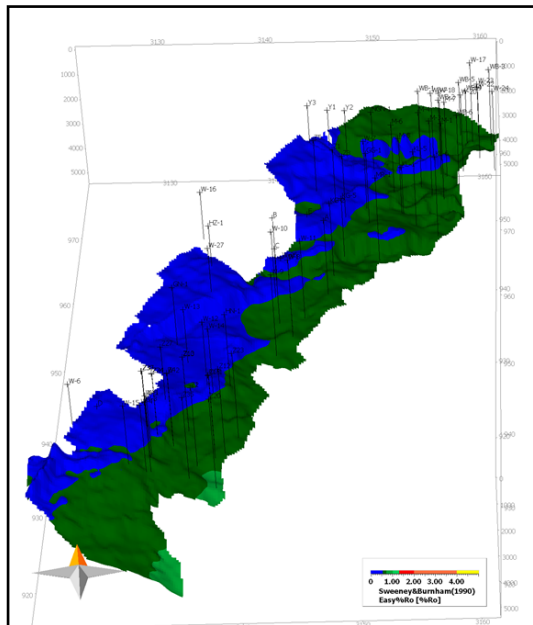


Figure 5: Rock Maturity at base of Sylhet

Critical moment is not yet attained by any of the source layers. Only early oil generation is observed in the model which is in line with the low TRs attained by the deepest source layer (not more than 23%) In this case the petroleum system model is inept to depict migration pathways.

Scenario-II Early Generating Custom Kinetics:

However the source rock studies indicate presence of source layers / source rocks which have early generation as well expulsion. Appropriate early generating source kinetics as discussed in pre-para has been applied to the model to understand migration pathways. In this case inspite of low maturity of the modeled area the transformations within the source layers are sufficient enough to expel hydrocarbons Figure 6.

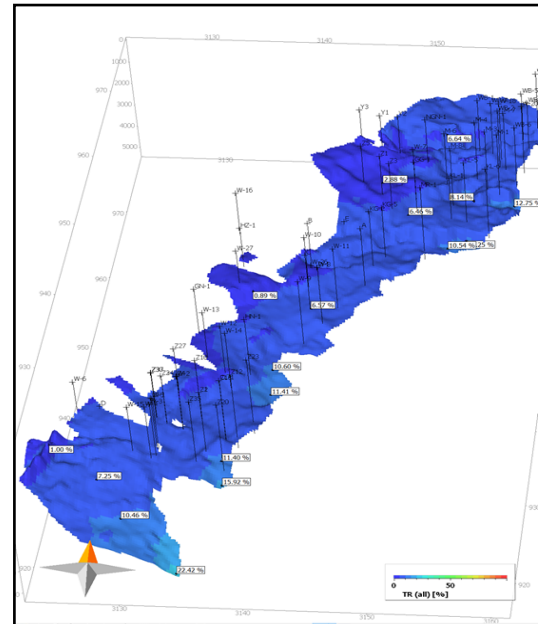


Figure 6: Transformation Ratio of Barail Source Rocks

The Early generating source rock kinetics shows there is less than 8% generation of the total generation potential in the study area. Out of which only 50% is expelled which is ~4% of the total hydrocarbon generation potential. The expelled volumes are low but it still helps in depicting migration pathways from source to reservoir. The expulsion vs time curves indicate that most of the expulsion and migration flux is post Mid-Miocene in the area. Migration modeling was performed to understand the possible migration pathways from kitchen to accumulations and identify risks/new areas for further exploration

The early generating kinetics model explains charging as well as non-charging of the some of the structures. Area is oil prone and modeled migration pathways indicate that charging of structures and further spilling towards structures in the western fringe up dip. The first set of migration pathways observed indicate that well W-10 is not in migration pathway but Prospect 'A' SE of well W-10 gets charged in the model. In all probability if hydrocarbon is struck at Prospect 'A' then the southwest extension of the Prospect 'A' may also be looked into as a future target (Figure 7).

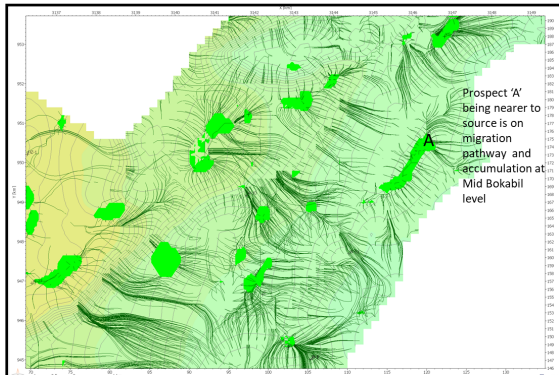
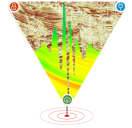


Figure 7: Accumulations observed at Prospect 'A'

The migration pathways depict that well KG-1 is in migration path way but this well is dry. This can be attributed to lack of sufficient charge migrating to well KG-1 fault block. The block adjacent to in which identified prospect 'B' is located though structurally high, falls on the same migration pathway to well KG-1, should therefore be a high risk due to insufficient charge in this fault corridor. The entire corridor has only one proven migration pathway within Mid Bokabil at well KG-2 structure bound by two scissor like faults, thus targeting the Mid Bokabil migration pathway further downdip E-NE of well KG-2, might have lower risks(Figure 8) .

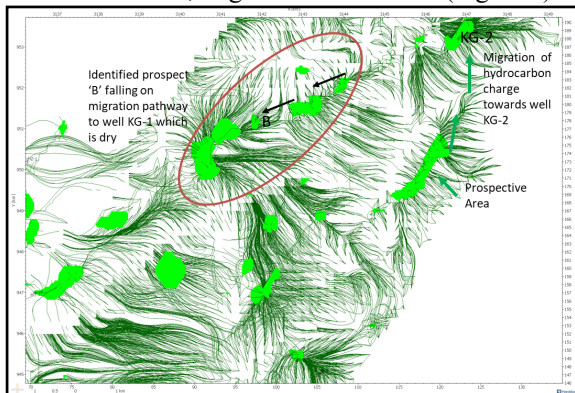


Figure 8: Hydrocarbon charge risk for Prospect 'B'

Well Z-27 drilled in the western most flanks is dry well. The modeled scenarios, NNW of well Z-27, show accumulations at multiple levels. Modeling results show migrating hydrocarbons are spilling / migrating in from NE corridor where well W-12 is already charged within Bokabil. The multiple scenarios show migration pathways towards this area and hydrocarbons spilling from multiple directions.

Hydrocarbon accumulations are observed near the prospect 'D'. The area might be prospective as hydrocarbon migration is observed from multiple directions into this area and spilling of hydrocarbons from adjacent field (Figure 9).

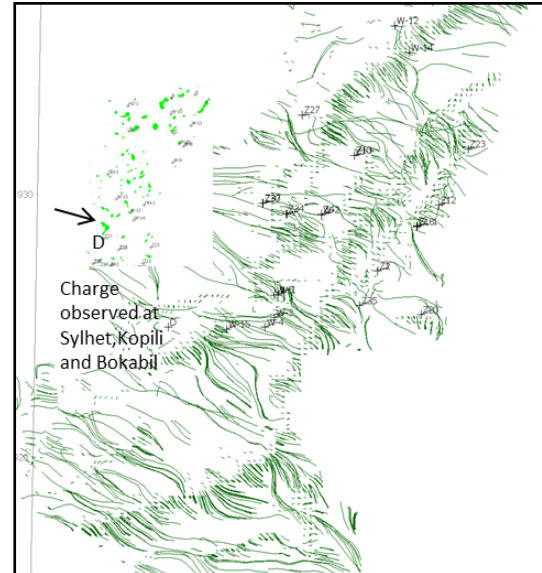


Figure 9: Multiple migration pathways to Prospect 'D'

Scenario-III Fault Property: Faults are playing a pivotal role in establishing migration pathways and charging of reservoirs with increasing influence for stratigraphically younger plays. This can be explained by fault seal vis -a-vis the throw at Tura, Sylhet and Kopili level being higher compared to that observed for Bokabil level. The higher throws in fault block has helped vertical migration as well as across the faults. The fault closures with smaller throws being sealing and structure getting charged (Figure 10).

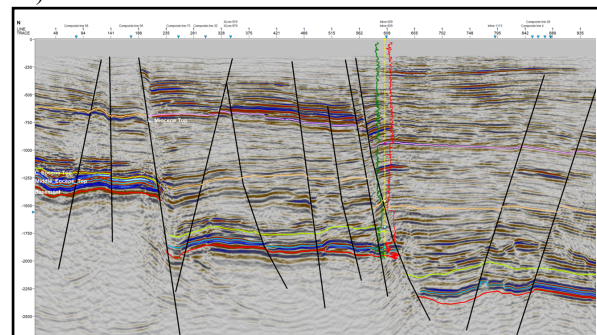
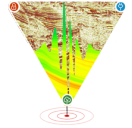


Figure 10: Seismic showing throws against faults



Two scenarios have been modeled, one with selected faults kept open for migration during a specified age and in second faults kept closed for migration during a specified age. The scenario modeled without faults show no hydrocarbon migration into shallower reservoirs such as Bokabils & Tipams and in some scenarios even Barail reservoirs don't get charged without faults. Faults therefore have a role in vertical migration of the hydrocarbons to shallower reservoir levels (Figure 11).

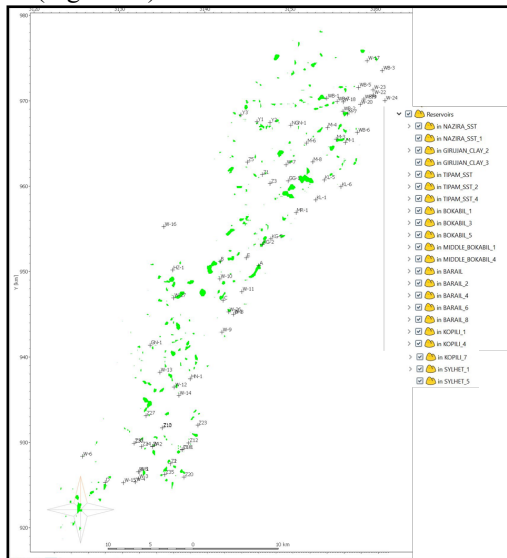


Figure 11: Total Accumulations in fault open scenario

The charge model also gives a clearer picture of the migration pathways with the fill-spill pattern getting depicted at multiple reservoir levels. It is also observed that the fill-spill pattern has helped charge the furthest structures in the western margin with the late charge i.e. gaseous hydrocarbon (Figure 12).

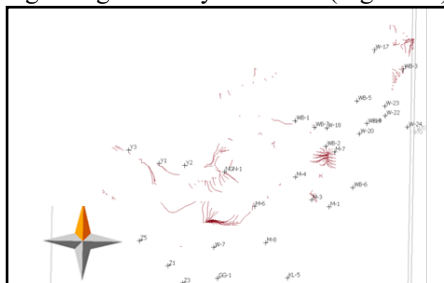


Figure 12: Migration pathways to furthest structure

Conclusions

Faults play a major impact on controlling both vertical and lateral migration and entrapment of hydrocarbons. The maturity data for the source rocks indicate early oil generation window on the shelf. Nevertheless there are source rock layers which are capable of generating at lower maturity. Based on this data customised early generating kinetics was formulated, which has shown that potential source rocks are capable of generating hydrocarbons. The generated and expelled volumes are low but it still depicts migration pathways and reduces charge risk. Based on migration modeling, a fill-spill pattern of reservoir filling at multiple levels is envisaged with faults having impact on hydrocarbon migration and accumulation. It is observed that in the modeled scenarios, existing established hydrocarbon finds are calibrated and some prospective locales are observed. These prospective locales are promising enough to be considered for further exploration.

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