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Evidence of Oligocene unconformity extending down to Eocene (Kopili Formation)-a case study from Dhansiri Valley

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Abstract

Since geological past A&AA Basin has evolved through series of tectonic events which led to formation of different structural traps for the accumulation of hydrocarbons in Tertiary plays & Fractured Basement. ONGC's exploratory activity in A&AA Basin has established the potential plays of Dhansiri Valley and their key petroleum system elements. Kopili is such a play whose source rock potential is well known but its reservoir facies analysis viz.-a-viz. hydrocarbon accumulation is not well understood. Oligocene unconformity has resulted in prolonged erosion of Barail Formation in Dhansiri Valley. Interestingly the index microfossil assemblage in some drilled wells indicates that the post-Barail unconformity extended down to the Upper Eocene Sediments (~ Kopili Formation). Microscopic sedimentological studies of Kopili explain the sporadic occurrences of the hydrocarbon pools and its relation to Reservoir Facies Characterization for the play. This study has incorporated the seismic 3D data (PSTM) interpretation along with sedimentological, micro-palaeontological and available G&G inputs to bring out the depositional model, sand distribution pattern and erosional nature of Kopili Formation. Building 3D Geological Facies Modeling of Kopili Formation from field and subsurface data using Sequential Simulation Indicator (SIS) algorithm delineates the presence of reservoir facies within Kopili in Dhansiri Valley.

Introduction

The Assam and Assam-Arakan basin has been a major contributor of Oil & Gas to India to Indian oil industry since 1889. Several tertiary petroleum plays have played an important role in contributing hydrocarbon throughout different areas of the A&AA Basin. Beside the established petroleum plays, the potential of the emerging new plays in different areas of the basin are yet to be explored. Amongst the emerging plays in Upper Assam Shelf – South area also known as Dhansiri valley, Kopili is one such formation whose source rock capability is well known but its reservoir rock potential is less explored (Singh R.K et. al., 2008). Broadly the distribution of sands in the Kopili formation is dependent on the depositional environment and tectonic setup of the basin. In our study area we cover the Upper Assam Shelf –South area of the A&AA Basin where the facies distributions are studied within lithological and sequence stratigraphic framework of Kopili Formation. The objective of the study is to bring out the depositional model, sand distribution pattern, prospectivity analysis and erosional nature of Kopili Formation as a result of Oligocene Barail unconformity extending and eroding the Kopili Formation in some parts of study area. All the work has been supported by the index microfossil data and lab reports of the cutting samples taken during drilling of Kopili Formation.

Regional Geology

Upper Assam Shelf as a part of the Assam & Assam Arakan Basin has long been established as a hydrocarbon producing basin in north eastern part of India. Geologically this is the north-eastern prolongation of the Indian Peninsular Shield with Garo-Rajmahal traps in between (Murthy et. al., 1983). The Shelf is bounded by the Mishimi Metamorphics in the northeast, Naga Schuppen belt to the southeast and Shillong Plateau along with Mikir Hills Basement Uplift in the southwest. The Upper Assam Shelf is further divided into Upper Assam Shelf North and Upper Assam Shelf South by an E-W trending Jorhat Fault (Evans et. al., 1964). The study area for the present work is the entire Upper Assam Shelf South also known as Dhansiri Valley (Fig. 1).

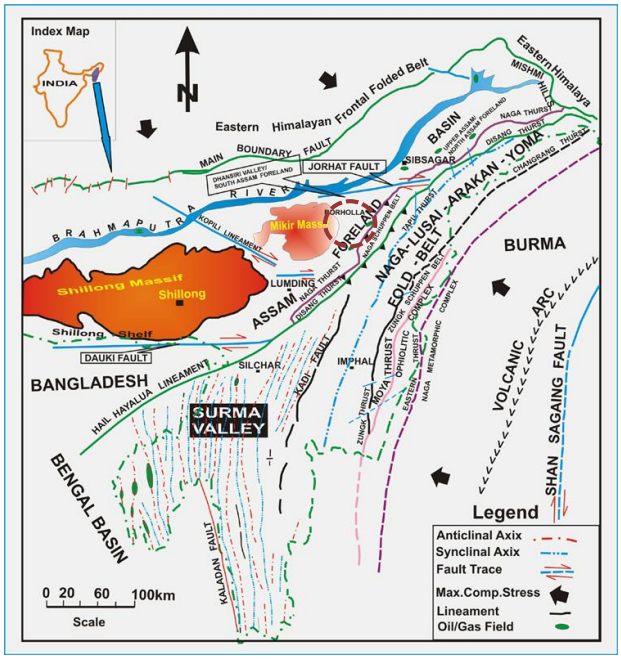

Figure 1:Structural elements in and around our study area

tectonic evolution of the Dhansiri valley is characterized by rift, drift and collision stages. The rift stage is evidenced in the intra-cratonic graben filled sediments aged as Permian to Early Cretaceous age. While the drift stage is marked by the Late Cretaceous-Oligocene passive margin sequence witnessing differential erosion at places, the foreland sequences are represented by a thick pile of extensive Miocene to Recent sediments (Bhandari et al. 1973). A number of major normal faults trending NE-SW or ENE-WSW direction have compartmentalized the Upper Assam Shelf South area. Another set of faults trending NNW-SSE and almost E-W have criss-crossed the whole area. The generalized stratigraphy of Dhansiri Valley is given below (Fig.2).

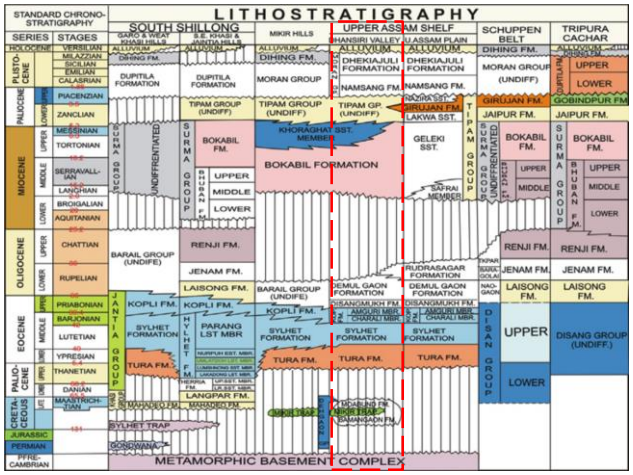

Figure 2: Generalised Stratigraphy of A&AA Basin

The sedimentary cover in the area is controlled by the irregularities in the Basement surface attributed to the tectonic subsidence, accommodation space and sediment supply. The sedimentary record in the area commenced during Paleogene in Passive Margin setting with the deposition of fluvial to marine coarse clastic sediments. This was followed by widespread transgression during Middle Eocene leading to deposition of carbonate sediments. The basal sandstone, Sylhet and Kopili Formations were deposited during this long time span of deposition. The transition from carbonates to coarser clastics during Oligocene can be attributed to tectonic uplifts in the provenance as well as falling sea level. The time was marked by extensive Oligocene unconformity leading to differential erosion of the Barail sediments. The successive orogenic phase during Late Miocene to Pliocene resulted in emergence of landforms. The Basin during the time came under fluvial depositional environment giving rise to composite sand bodies of the Tipam and the younger sediments.

Methodology

In order to understand the regional variation of lithofacies and to depict the structural disposition as well as reservoir facies extension for Kopili Formation of the study area the following methodology has been used.

Seismic Data Interpretation: The study has been interpreted using available 3D Seismic data. Three seismic vintages were considered for analyzing the prospectivity of the established as well as potential plays of the study area with special emphasis to Lower Kopili and Upper Kopili formations. Regional as well as prospect level maps for entire study area at both the levels were prepared.

Synthetic Seismogram: The seismic vintages were calibrated with well picks with the help of synthetic seismogram.

Horizon correlation & Fault Mapping: Horizon correlation and fault mapping were carried out simultaneously for the three 3D seismic vintages. Three major fault systems were observed and interpreted, older NE-SW trending normal faults formed during extensional regime and NW-SE & E-W trending faults which are formed later during compressional regime.

Time and Depth Structure Maps: Time Relief, Time Structure and structure maps were prepared close to the top of Lower Kopili and Upper Kopili formations in the study area (Fig. 3 & 4).

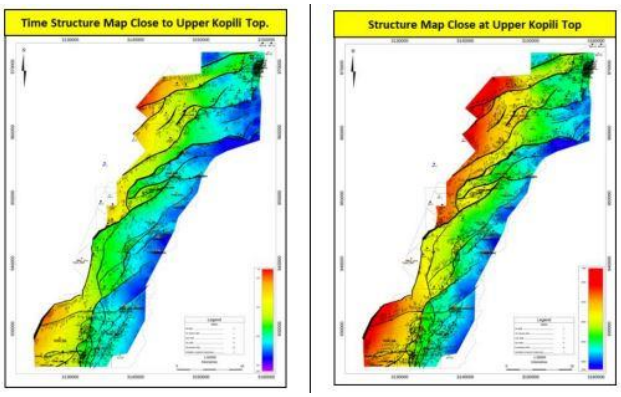

Figure 3: Time Structure and Structure Map of Upper Kopili

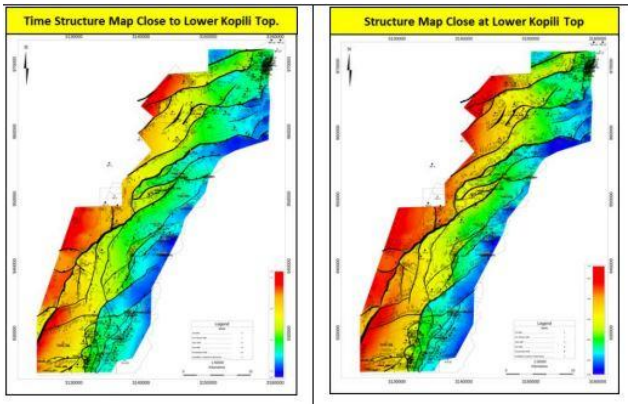

Figure 4: Time Structure and Structure Map of Lower Kopili

Lithological Classification: Based on lithological characteristics, attempt has been made to divide Kopili Formation into Lower and Upper Kopili units in the entire study area. The same has been validated by integrating the

stratigraphy laboratory data which shows marked variation in the log characteristics vis. a vis. foraminifera frequency in the Upper and Lower Kopili units. Lower Kopili Formation is characterized by an overall aggrading shaly sequence with intervening sandstones and carbonate streaks in between. Lower Kopili Top is marked by a distinct shale top marker which is uniformly present throughout the study area. Upper Kopili Formation is represented by an overall prograding sequence with shales and sandstones as the major facies associations.

Log Correlation: Log correlation of the key wells has been carried out extensively, both in dip and strike direction, covering the entire area under study. Three strike profiles covering western corridor, central corridor and eastern corridor of the study area has been prepared and studied. Log correlations in dip direction has been prepared for Khoraghat, Dayalpur and Borholla areas and studied to understand the facies variation across the Dhansiri Valley. Log motifs of the five 3rd order system tracts identified within Lower Kopili unit has been analyzed to depict the depositional set-up.

Sequence Stratigraphic Analysis: Kopili Formation represents a regressive unit of the 2nd order Passive Margin sequence of Assam Shelf succeeding the drowning of Mid Eocene Carbonate (37.2 ma) which is a 2nd order mfs (Moulik et. al., 2009). Sedimentation during this time continued with progradation and aggradation along with supply of clastics till the accommodation was over filled and delta prograded to the south east. In our Study area five 3rdorder System tracts (STs) were identified within Lower Kopili Formation and four 3rd order STs were identified within Upper Kopili Formation. However due to the erosional nature of the Upper Kopili unit, its thickness is highly variable and the traceability of the STs are restricted in many places in the study area.

Thickness Map & Depositional Model: Regional Isopach map and regional sand Isolith maps were prepared for Upper Kopili, Lower Kopili and total Kopili Formation to delineate the sediment depo-centers and the reservoir facies distribution patterns (Fig. 5 & 6).

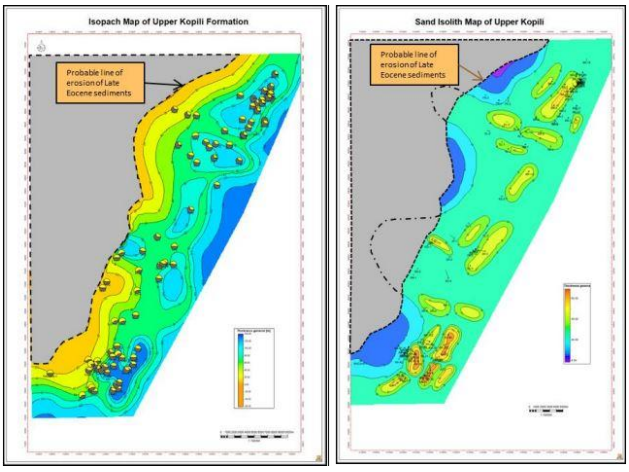

Figure 5: Isopach & Sand Isolith Map of Upper Kopili Formation

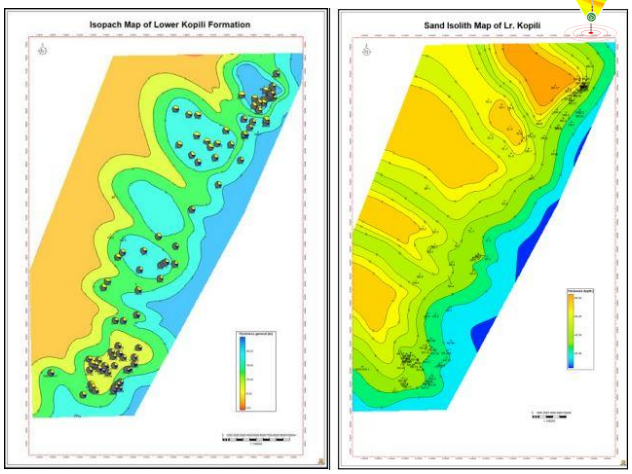

Figure 6: Isopach & Sand Isolith Map of Lower Kopili Formation

On the basis of present study, detailed analysis of the depositional model of Kopili has been carried out. The prepared isopach and sand isolith maps integrated with bio stratigraphic lab data shows two different depositional set up for the Lower and Upper Kopili units. Available literatures on Kopili Formation were taken into consideration and the views expressed by the previous workers lend support to the prepared model (Fig.7). Overall an estuarine – embayment type of depositional setting has been inferred for the Kopili Formation [Naik et. al.(2001), Salman Zaidi et.al.(2002)]. In general it may be concluded that Kopili Formation was deposited in a shallow marine nearshore to coastal transitional setting under medium to low hydrodynamic energy conditions.

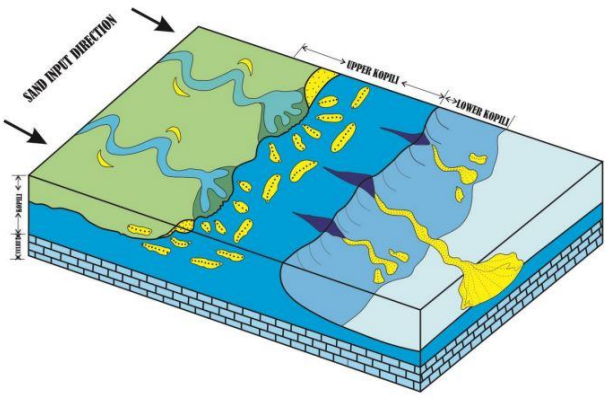

Figure 7: Depositional Model of Kopili Formation in the study area

Facies Analysis: To understand the geological characterization of reservoir facies, the Facies modeling module of Petrel has been used to create a realistic representation of the depositional facies or lithologies in the study area. Up scaling of high-resolution well log data has been carried out and depth structure map close to Kopili Top was used as input. Trends of unit-wise sand isolith maps are used to indicate the input direction of reservoir facies for the 3rd order System Tracts identified in Lower Kopili Unit.

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The Lower Kopili unit has been found to be more or less consistent throughout the study area and can be well correlated in wells as well as seismic data. The uniformity in litho-association and traceability over large areas suggest a stable and calm environment of deposition for the unit. Presence of marl/limestone streaks indicate slow rate of deposition (Galloway et. al., 1989). Based on the present study, it has been inferred that the Lower Kopili unit has been deposited under shallow marine conditions in an inner shelf environment. During the deposition of Upper Kopili unit, sediment influx was relatively higher resulting in development of a framework of estuarine environment i.e. Barrier bar-lagoon-tidal flat complexes in a very shallow marine to transitional set up of environment (Narsimha et. al.,2019). The Upper Kopili unit has been observed to be restricted in its disposition with pronounced erosional activity during Oligocene towards the western margin of the study area.

As we move towards the western margin from east, the Upper Kopili along with Lower Kopili decreases in thickness. The decrease in thickness is further pronounced because of the erosion of Late Eocene Upper Kopili sediments along the western margin which is demonstrated in well KE-1 in the section. Further west, across the NE-SW trending fault, both the Upper Kopili and Lower Kopili Horizons were merged and correlated as one as thickness of Upper Kopili reduces to 10 m and is not resolvable in seismic data.

Time Relief Map of Lower Kopili Formation indicates that the surface dips towards south-eastern direction with the shallowest part towards north-west. Both the time and depth maps correlate and follow the same trend. Structures are mostly fault-bounded and four-way closures. In general Upper Kopili surface mimics the Lower Kopili formation and dips towards southern eastern direction.

Corresponding isopach maps of Upper Kopili and Lower Kopili units also suggest gradual increase in thickness from Northwest towards basinal dip in Southeast direction. Sand isolith map of Lower Kopili shows that sandy facies are distributed across the study area with thicker layers of sands were developed towards north-eastern side in and around East Lakhibari - Borholla area.

The Upper Kopili unit as an erosional layer has restricted occurrence at places. As per the present study, the thickness of the unit is highly variable at places and has adversely affected the traceability of the identified 3rd order System Tracts within the Upper Kopili unit. Hence the Facies analysis in the present study has been confined to the Lower Kopili unit only. Also it is pertinent to mention that the hydrocarbon bearing Kopili pay sands in the study area are mainly confined to the Lower Unit (i.e. 3rd & 4th System tract); detail analysis of the facies association within the pack is of utmost importance (Fig.8).

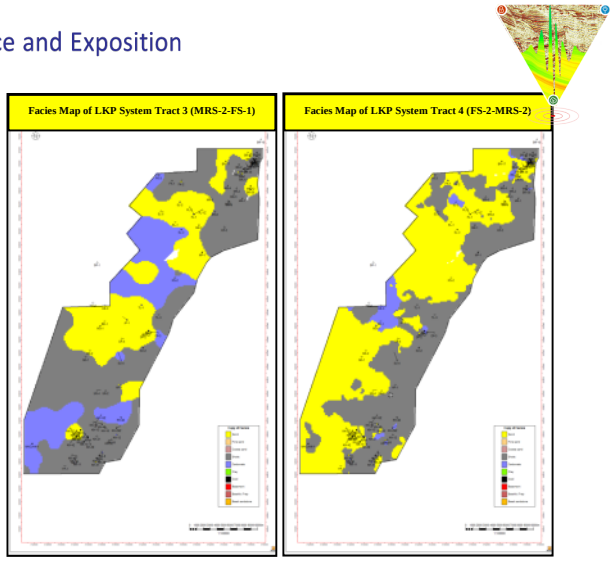

Figure 8: Reservoir Facies Map of Lower Kopili 3rd order System Tract 3 & 4

In well KE-2 the log signature of Upper Kopili mimics Barail sand like nature but core cut in that interval suggests no reported Oligocene markers in the foraminiferal assemblage rather Dinocyst sp. has been reported which is an index fossil of Late Eocene age. Thus it was concluded using the Regional Geoscience Lab report that the sediments of Oligocene as well as the topmost part of Late Eocene might were eroded in the well KE-2 (Fig. 9).

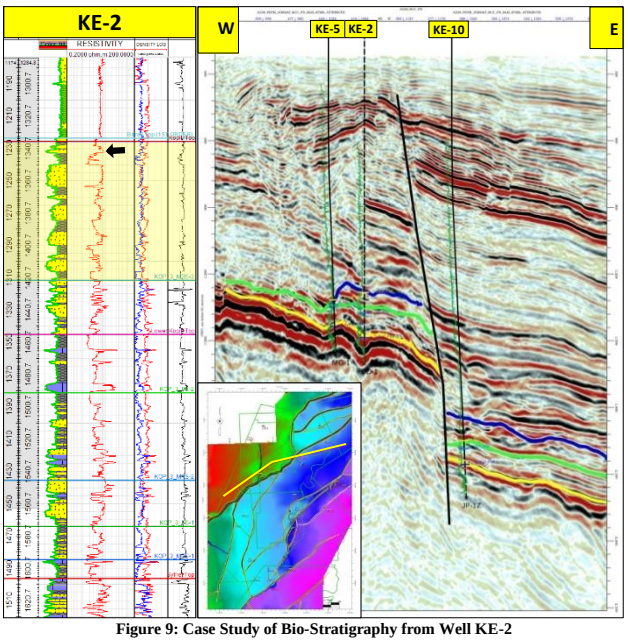

Figure 9: Case Study of Bio-Stratigraphy from Well KE-2

Similar erosional nature of Kopili was found in other wells in western margin of Dhansiri valley which has been also validated in seismic sections and accordingly a erosional boundary was drawn during preparation of Time (Relief and Structure), Depth and Sand maps (Isolith & Isopach) of Upper Kopili formation.

Conclusion

Kopili formation has not been classified in previous studies in a regional scale in Dhansiri Valley. After this study the depositional environment and reservoir

cteristics of the Upper and Lower Kopili formation is well understood. Upper Kopili formation exhibits variation in thickness due to an extensive unconformity towards the western margin of the block. The erosional nature is observed in the wells KE-3, KE-4, KE-2, and KE-5 as well as in the seismic sections. Interestingly erosional nature of the Lower Kopili formation is also observed in wells KE-6, KE-7, KE-8 & KE-9. The same has been validated by the microfossil assemblage of core cut in well KE-2 from the study area. Thus, the finding implies that the Late Eocene sediments are eroded along with the Oligocene sequences towards the western margin of the Dhansiri valley. The study brought out a classified and well-defined depositional model for the Kopili Formation where it was inferred that the Lower Kopili formation was deposited under shallow marine condition whereas the Upper Kopili formation is attributed to the estuarine environment, i.e., Barrier bar-lagoon-tidal flat complexes in a very shallow marine to transitional setup.

Reservoir facies analysis viz-a-viz hydrocarbon accumulation was also carried out. The primary porosity of Kopili plays a significant role in the accumulation of hydrocarbon. It has been inferred that as a result of destruction of primary porosity in several areas such as Khoraghat field of Dhansiri Valley due to calcite & ferruginous cementation, hydrocarbon success is sporadic and limited for Kopili play. Despite the aforesaid condition, development of reservoir facies is also observed in few pay sands of Lower Kopili formation. The provenance of the calcite cement is envisaged as the outcrops of lime stones from NW. Moreover the absence of hydrocarbon in the Upper Kopili formation can be attributed to the absence of cap rock and local erosional nature. Based on the Sequence Stratigraphic Framework five system tracts were identified, among which the 3rd and 4th System tracts are well correlated with the hydrocarbon pays of Lower Kopili in Dhansiri Valley.

The objective of the study is to bring out the erosional nature, depositional model, sand distribution pattern and prospectivity analysis of Kopili Formation in a regional scale in Dhansiri Valley. Reservoir facies analysis of Lower Kopili play indicates that porosity destruction is an impeding factor for the limited success of the play in Dhansiri valley. The study concludes that the western part of the Dhansiri is less interesting for exploring the Upper Kopili play because of the extensive Oligocene unconformity and absence of proper seal above while porosity destruction is an important factor for Prospectivity of the Lower Kopili pays.

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