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Author **Jatindra Samal , ONGC , India**

Co-Authors **Debendra Taid, Swati Samadder, A. C. Naithani, Dhruvendra Singh**

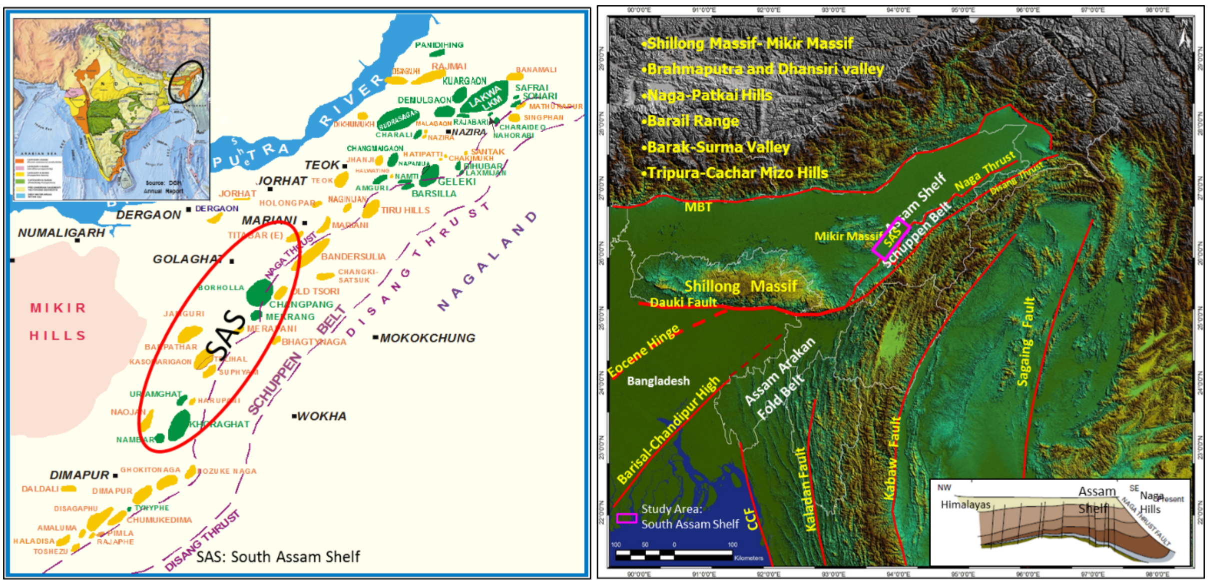
3D Facies Modelling of thin sands in a complex Geological set up: Case study from South Assam Shelf, NE India.

Abstract

Bokabil Formation of Miocene age constitutes more than 65% of the total oil in-place in South Assam Shelf, a part of Assam and Assam Arakan Basin and has several surprises and challenges. Sands within Bokabil Formation are thin and discrete in nature. There is a challenge in the delineation of thin sand reservoirs vertically and spatially, which holds good potential for further exploration. For better understanding of the depositional sequences, the work was carried out in sequence stratigraphic framework for identification and interpretation of different depositional units and it depicted the producing reservoir sands of Bokabil Formation were deposited in the Transgressive System Tract (TST) zone. The TST of IInd order FD-1 has been subdivided into four genetic sequences on the basis of three flooding surfaces. Lithological it consists of mainly shale with thin sand bodies. Paleogeography maps have brought out coast lines and sediment input directions and sand thickness maps of different units helped in bringing out idea on sediment dispersal pattern. 3D Facies Modelling has been attempted using Landmark's Decision space Earth Modelling module to understand the spatial variability and connectivity of reservoir properties. The TST zone of interest was modeled to understand the distribution of the thin sand bodies. The model output clearly brings out the extent of the sands in vertical and lateral direction. The results were validated with the known pay sands and in integration of other studies, the output has been used in identification of future prospective areas. The output is very much useful in de-risking in both Exploration and development front.

Introduction

South Assam Shelf, a part of Assam and Assam Arakan Basin, NE India (Figure 1a) is endowed with hydrocarbon accumulations in multiple reservoirs from Pre-Cambrian fractured basement to Mio-Pliocene sequences. So far, Basement, Sylhet, Barail and Bokabil formations have been established as commercial hydrocarbon producers from different pays. Though Bokabil Formation is the mjor producer, still it has several surprises and challenges. Thin and discrete nature of sands possess, major challenge in the delineation of thin sand reservoirs, which holds a good potential for further exploration. Understanding of the depositional sequences and re-construction of paleogeography is the prime requirement for facies distribution analysis of the Bokabil Formation. To overcome the challenges, work was carried out in a high resolution sequence stratigraphic framework for better understanding of the depositional sequences. To address thin sands, 3D Facies modelling was



carried out to understand the spatial variability and connectivity of reservoir properties. In the study, the thickness of each layer was considered 3m. Hence, within a pack of sands, individual layer wise (3m) vertical and aerial extent can be delineated from the study.

Geology, Tectonics and Stratigraphy

South Assam Shelf (SAS) encompassing the geographical extent of Dhansiri Valley forms a thrust bounded basin which had undergone multiple episode of tectonism. It is flanked by NE-SW trending mobile Naga Schuppen belt on the east and southeast and Mikir massif in the west, whereas, Jorhat fault bounds it in the north separating it from rest of the Assam Shelf (Figure 1b). Basement is gently dipping towards southeast and it is dissected by several NE-SW trending Basement involved longitudinal normal / reverse faults hading both towards southeast and south west. Many transverse normal faults trending in approximately in E-W direction are also present. These fault systems divide the field in different local horst and grabens (Rangarao, 1993). Granitic - gneissic complex constitutes the basement for sedimentary sequences of Tertiary age. The sedimentation started in Paleocene and continued till recent with an unconformity during Oligocene and Mio-Pliocene. In addition, Gondwana sediments have also been found in small localized grabens. As per litho-stratigraphy (Deshpandey et.al, 1993), in SAS area the Bokabil Formation includes Bokabil (lower part) and Khoraghat sandstone member (upper part), which comes under Surma Group (Figure 2). The Bokabil Formation unconformably overlies Barail or Pre-Barail sediments. The upper contact is conformable and gradational with overlying Tipam group.

Figure1.a) Index Map showing the study area of South Assam Shelf (SAS) on Prospect Map. b) Regional Digital Elevation Map showing Physiographic division and Tectonics of A& AA Basin.

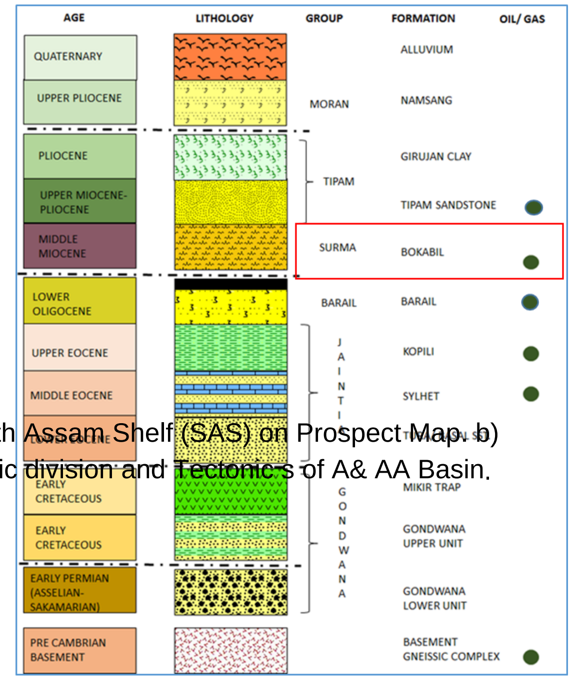


Figure 2: Stratigraphy & Hydrocarbon Habitat of South Assam Shelf

Bokabil Play in South Assam Shelf and Challenges

Bokabil constitutes more than 65% of the total oil in-place in SAS. Though Bokabil is a good producer, still there is a challenge in the delineation of thin sand reservoirs, which holds a good potential for further exploration. Recent success in one of the field in central part has opened new areas in central part. Major challenges in the area are complex geological setting, frequent facies variation, thin and discrete sands, low frequency sands having mapping challenge (Figure 3). The stacked sands are envisaged to continue further in and around the area.

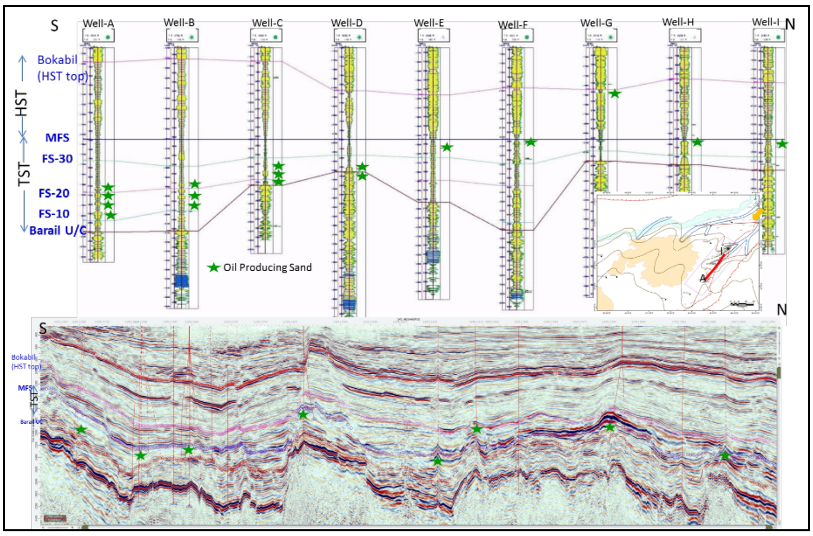


Figure3: Bokabil Pay Sand distribution on log and seismic. Major challenge of facies variation and thin, discrete nature of sand is well depicted.

Depositional Analysis: High Resolution Sequence Stratigraphic Approach

For better understanding of the depositional sequences, the work was carried out in a high resolution sequence stratigraphic framework and it depicted the producing reservoir sands of Bokabil Formation mostly were deposited in the Transgressive System Tract (TST) zone with Oligocene Barail unconformity at bottom (Figure 4). In the area, four first order sequences specific to four tectonic phases in the evolutionary history of the basin, which are related to Gondwana intra-cratonic grabens, Early Cretaceous rifts, Late Cretaceous to Oligocene passive margin peri-cratonic basins and post collision foreland basin systems are observed. The fourth 1st order foredeep sequence of Miocene to recent age has been divided into four 2nd order sequences.

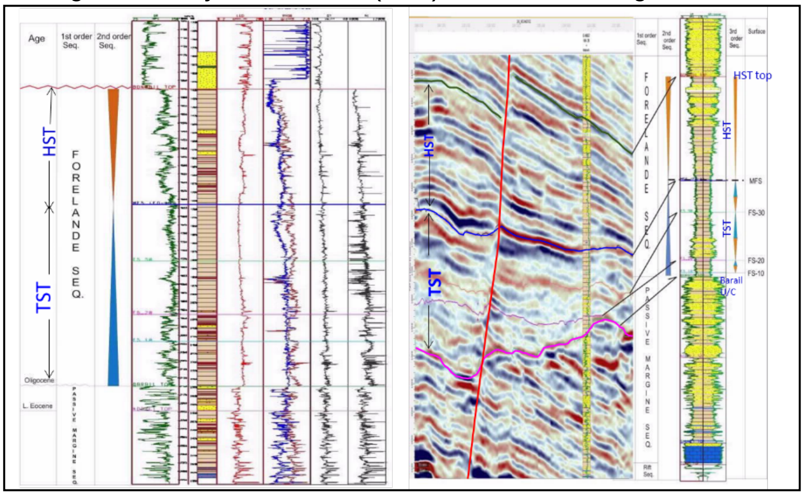
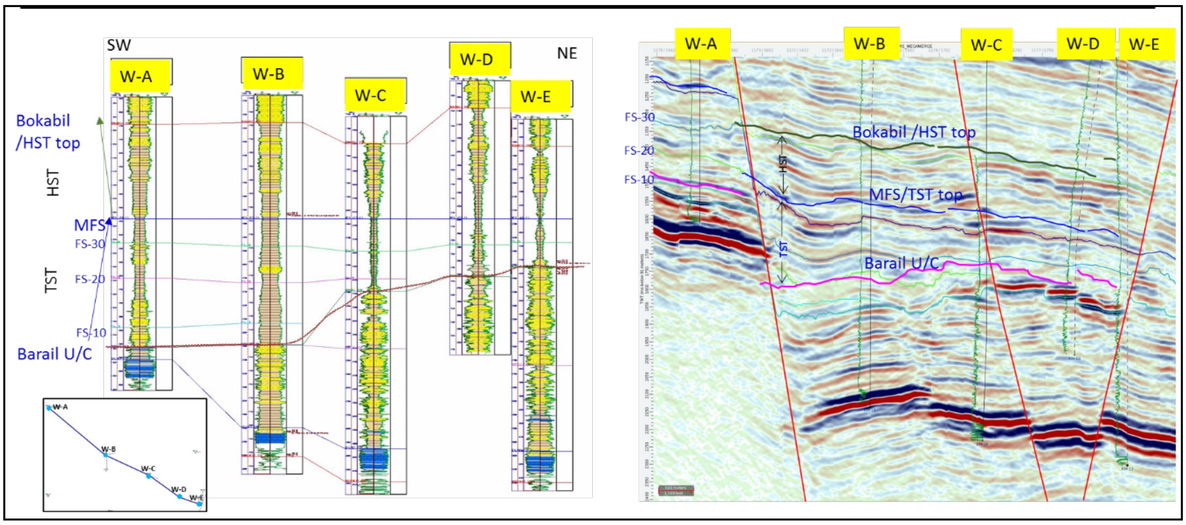


Figure4: Depositional Set up in Sequence Stratigraphic framework: identification of different Sequences

Present study is confined to the Bokabil Formation i.e. the first IInd order Foredeep Sequence and this has been further subdivided into 3rd order sequences. TST is characterized by finning up log motifs (Figure 4). These are essentially shore face sands which are progradational in nature, where sedimentary supply is more from the nearby coast and thus, out-building has taken place. In seismic, the bottom part of this sequence is represented by medium to high amplitude parallel reflections corresponding to reworked transgressive sands. These sediments are differentially eroded by third order unconformities towards the top resulting in geomorphic features which are clearly seen on 3D seismic data. The top part of the sequence is represented by nearly transparent /weak reflection zone corresponding to argillaceous facies. The top of the sequence FD-1_MFS is represented by weak to moderate amplitude events with poor to good correlatability (Figure 4).



Subdivision of TST into 3rd order sequences

The TST of IInd order FD-1 has been subdivided into four genetic sequences on the basis of three flooding surfaces viz. FS-10, FS-20 and FS-30 (Figure 5). As the marine transgression encroached the area, the accommodation space became available for deposition of sands which are the reservoir units within Lower Bokabil. The sands in the units of FS-10, FS-20 and FS-30 have been derived from the nearby geomorphic highs of Barail unit and the sands are back stepping in nature. Dip profile shows the thickness variation of FS-10, FS-20 and FS-30, which is clearly evident in both log and seismic. Truncations against the paleo Barail high are clearly observed on both, log and seismic (Figure 5).

Paleogeography and Sand thickness Maps

Paleogeography maps close to top part of Barail and HST of FD-1 infers the coast lines and sediment input directions (Figure 6). Up to Barail, the input direction was from NW which has been marked on the map. During HST time, the sediment input direction was from NE to SW (Figure 6).Gross sand thickness maps for FS-20 unit (Barail & FS-20), FS-30 unit (Barail and FS-30) and unit between MFS and FS-30 helped in understanding the regional sand distribution pattern (Figure 7).

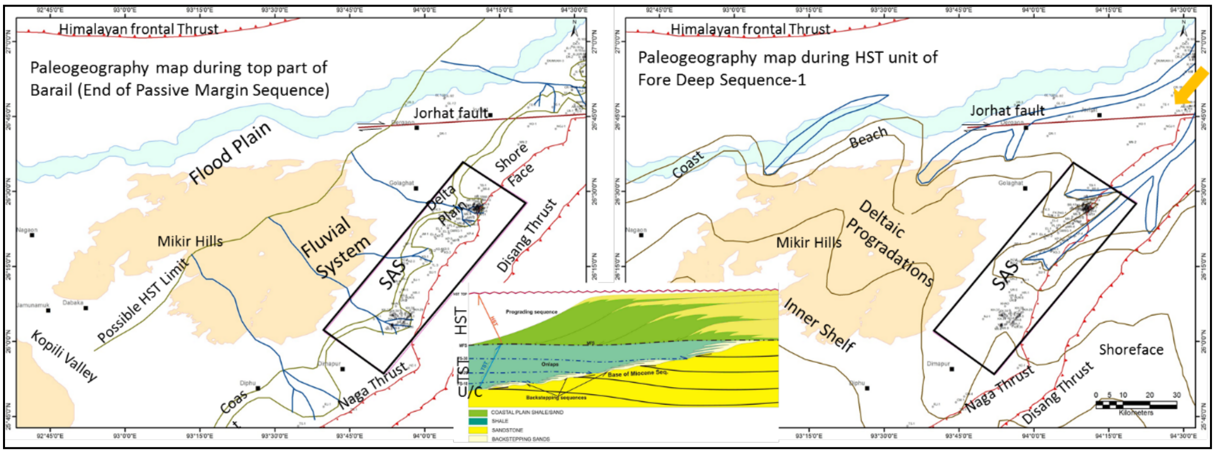


Figure 6: Paleogeography Maps during Barail top and Bokabil

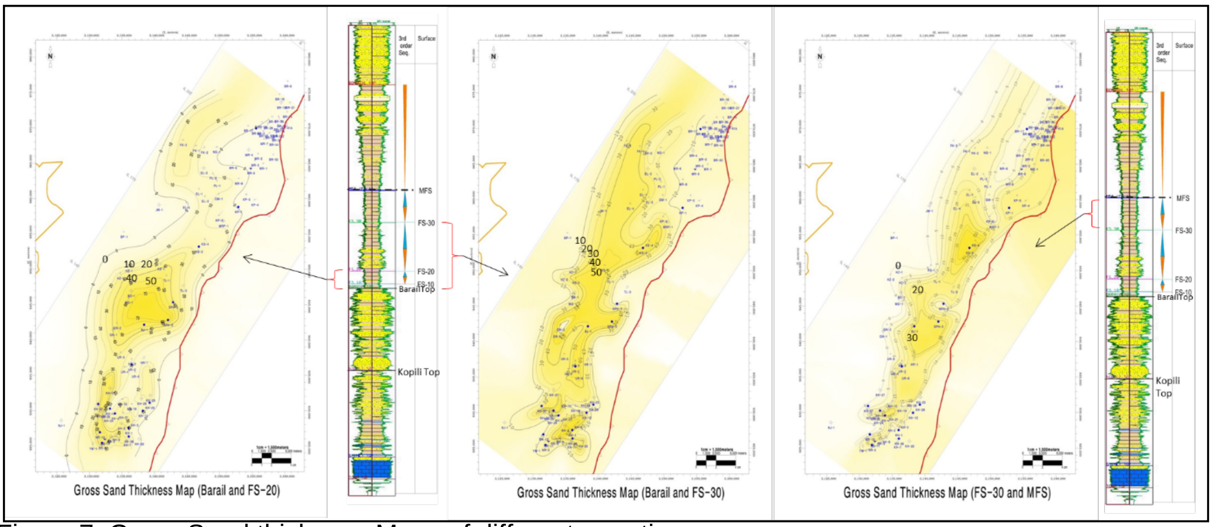
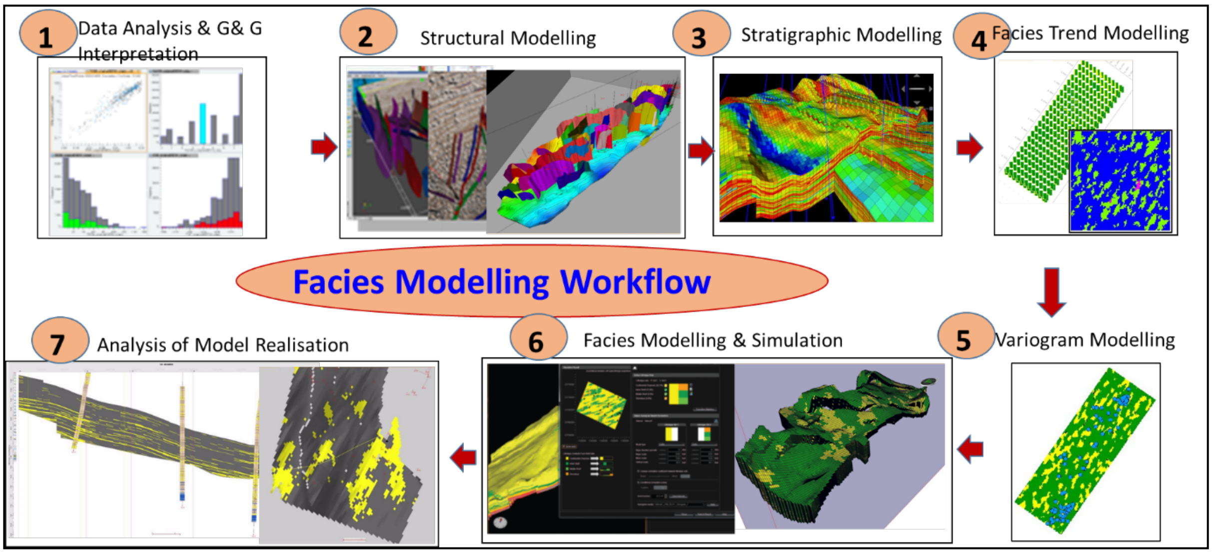


Figure 7: Gross Sand thickness Maps of different genetic sequences

3D Facies Modelling

To understand the spatial variability and connectivity of reservoir properties, 3D Facies modelling was carried out using Landmark's Decision space Earth modelling module (Figure 8). The TST zone of interest has been modeled to understand the distribution of the thin sand bodies. The structural model was constructed using depositional sequences and major faults delineated using 3D seismic data and depth markers measured along the wells. Through Stratigraphic Modeling, a 3D geocellular grid was built, which is stratigraphically layered with defined lithotypes and assigned facies to the lithotypes. Then well log data have been blocked to the grid. Seismic Attribute Blocking was used to block the 3D seismic attribute volume onto a grid. Facies Trend Modeling was used to create a lithotype proportion map for use in Facies Modeling and Simulation and to calibrate seismic attributes to facies in blocked wells. Facies Simulation was carried out onto the grid using the variogram models computed in the facies modeling for each interval. Facies model was populated with Truncated Gaussian Simulation and Sequential Indicator Simulation algorithm. The objective was first to calibrate with the known pay sands and to delineate their extent in the southern part of the study area. In the study, the thickness of each layer was considered 3m, as we encounter thin sand bodies in Bokabil in these areas. Hence, within a pack of sands, individual layer wise (3m) vertical and aerial extent can be delineated from the study. The results show the extent of the sand bodies in section and also delineate the aerial extent of the sand bodies. Figures 9 and 10 show the extent of pay sand bodies of Field A. It also explains the



different sand bodies of Field A and Field B. The results were validated with the known pay sands (Figure 9) and in integration of other studies, the output has been used in identification of prospective areas. The model output clearly brings out the extent of the sands in vertical and lateral direction (Figure 10).

Figure 8: Facies Modelling Workflow

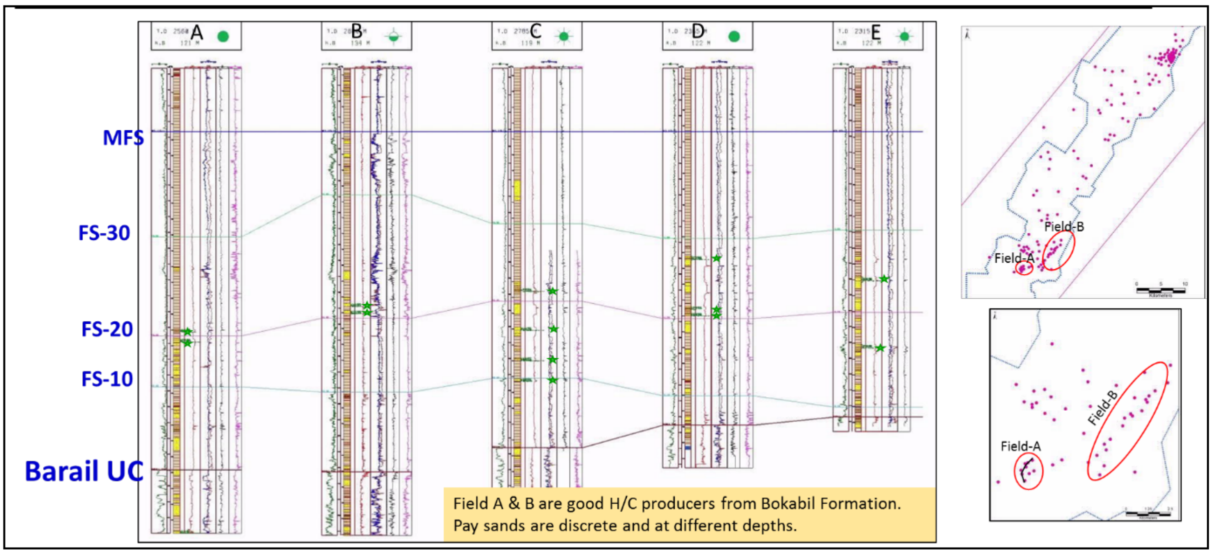
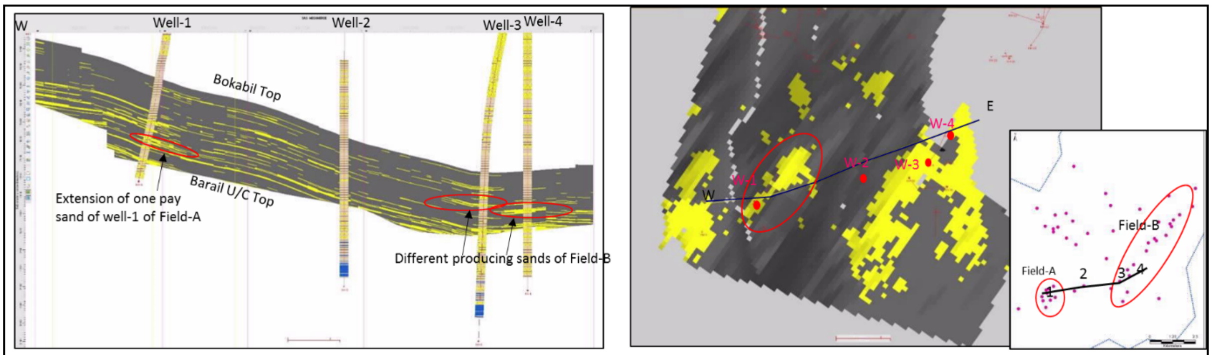


Figure 9: Analysis of Pay Sands of Field A



Facies model showing lateral extent of sand bodies

Facies map depicting the aerial extent of individual pay sand around well-1 of Field-A

Figure 10: Validation of Model results with known Pay sands. The model output clearly brings out the extent of the sands in vertical and lateral direction

Conclusions

Comprehensive study after identification and interpretation of different depositional units in a high resolution sequence stratigraphic framework helped to understand facies distribution and depositional setting. To address the challenge in the delineation of thin sand reservoirs within Miocene Bokabil Formation, 3D facies modelling has aptly been used. The model output clearly brings out the extent of the sands in vertical and lateral direction. The results were validated with the known pay sands and in integration of other studies, the output has been used in identification of future prospective areas. The output is very much useful in de-risking in both Exploration and development front. The results will be very much helpful for delineating thin reservoirs of other fields.

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References

Deshpande, S.V., S.M., Bhandari, A., Baruah, R.M., Deshpande, J. Arun Kumar, Rana, K.S., Chitrao, A.M., Giridhar, M. Choudhuri, D., Kale, A.S. and Phor,L. (1993). Lithostratigraphy of Indian petroliferous Basins, O.N.G.C. Doc-X Assam-Arakan Basin, Vol. 1 &II

Ranga Rao, A. (1993) Geology and Hydrocarbon potential of a part of Assam-Arakan Basin and its adjoining region, Petrol, Asia, Jour, Vol. 6 (4) PP.127-158