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Makum Field—High-Resolution Sedimentary Facies Modeling From Micro-resistivity Image Log Using New-Generation Dip Modeling Software

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Abstract

The Makum field of the Upper Assam Basin (Assam, India) is an elongated anticlinal structure bounded by NNE-SSW trending faults. This field is commercially producing oil from sandstone reservoirs of the Barail Formation of Oligocene age. Higher degree of heterogeneity due to lateral facies variation posed challenges while placing horizontals in different wells in this field.

The study is focused around two appraisal wells located in the south-western flank of Makum structure. This work demonstrates the combined use of high-resolution micro-resistivity images and openhole data to define internal sedimentary structures and lithology to generate high-resolution sedimentary facies within the two wells. The application of new-generation dip modeling software created a 3D structural model, which was used to propagate the sedimentary facies in 3D space away from the boreholes.

This 3D structural model illustrated that the prominent paleocurrent direction trends towards SE which corresponds to the basinal paleo-slope direction. The sedimentary facies were found to change from delta front to delta plain.

The study emphasizes the use of micro-resistivity image data to construct a high resolution facies model, which can reveal the facies distribution of a region providing valuable information to optimize well trajectories of horizontal wells in the formations of interest.

Introduction

The Makum-North Hapjan field of the Upper Assam Basin (Assam, India) is a faulted anticlinal structure with the major axis of the structure trending in NE-SW direction. The structure is bound by two NNE-SSW trending major normal faults in the NW and SE extremities (Fig. 1A). The Makum structure is separated by the North Hapjan structure by a series of collinear normal faults. This field is commercially producing oil from sandstone reservoirs of the Barail Formation of Oligocene age. Barail Formation consists of lower arenaceous unit which is a delta front sequence and upper argillaceous unit which is a part of upper delta plain sequence.

Horizontal wells have been drilled in the field to optimize and enhance production and to overcome land acquisition hassles. High degree of heterogeneity due to lateral facies variation posed challenges while placing horizontals in different wells in this field. Well A and Well B are two appraisal wells located in the Makum field and owned by Oil India Ltd. Well A is located NW of the Well B at a distance of about 2.0 km (Fig. 1B). The recorded micro-resistivity image logged intervals for these two wells lie in Barail Formation. High resolution sedimentary facies modelling was carried out for the two wells to understand the sedimentary and structural variations in between the two wells.

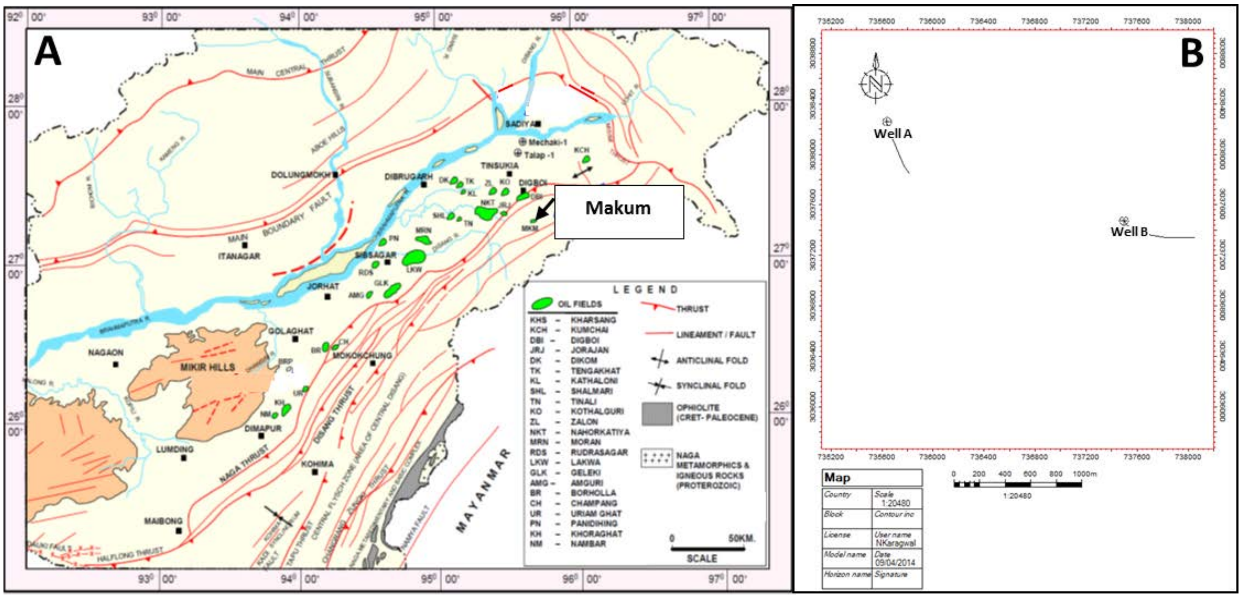

Figure 1A: Makum Field location in Upper Assam Basin. Figure 1B: Location of Well A and B in map view.

Objective

The Makum field poses a challenge when it comes to the documentation of the facies variations within the field because of its sedimentological intricacies. Lithological characterization is a challenge in the Makum field because of the presence of intervening shale layers within the oil producing thick Barail Arenaceous sand unit. Because of the lateral variations of this intervening shale layers, it is difficult to establish their continuity with confidence.

The main objective of the sedimentological studies undertaken for Well A and Well B was to understand the lateral extent and geometry of sedimentary facies occupying the area between the two wells. This work demonstrates the combined use of high-resolution micro-resistivity images and openhole data to define internal sedimentary structures and lithology to generate high-resolution sedimentary facies between the two wells. The application of new-generation dip modeling software created a 3D structural model based on high-resolution correlation, which was used to propagate the sedimentary facies in 3D space away from the boreholes. This dip and image log based application can resolve the fine scale geological complexities and it considerably reduces structural uncertainties in an existing 3D reservoir model.

Methodology

The current study utilized high-resolution micro-resistivity images and open hole log data for the two wells. The detailed multi-well micro-resistivity image facies and dip interpretation were used for understanding the various sedimentological and structural variations.

Manual dip interpretation using the high-resolution micro-resistivity image was carried out to act as the primary input for the 3-D structural and facies modelling. True stratigraphic thickness (TST) at borehole level was computed followed by stratigraphic correlation using TST indexed images/logs and well tops. Stratigraphic correlation was done for the two wells using gamma ray log guided by the already established well tops (Barail Argillaceous and Barail Arenaceous) and micro-resistivity image logs (Fig. 2). Global deposition events such as shale and coal deposits were used to correlate the wells.

The local structural dips were extracted by filtering the dip data using dip sequence analysis. A new-generation dip modeling software was used to project these structural dips around each well. The entire logged interval was found to be belonging to a single structural event and hence was classified as one structural unit and one structural element (Fig. 3). Isopach maps and surfaces were created using the TST data guided by the structural dip projection. Different geological surfaces were modeled honoring actual structural dip data from high resolution images.

For 3D sedimentological facies modelling purpose, property zonation logs were prepared based on open hole logs and further refined using the image logs. These zonation logs defined the lithology of the logged section. Sedimentary structure analysis was performed from the sedimentary surface dip sets, volume of clay and TST (Fig. 8). The sedimentary structure analysis was used to define the various facies and the depositional settings. Morpho-facies variation on the basis of micro-resistivity image log guided by the sedimentary bed attitudes was used to populate the data between the two wells. The paleo-slope direction and the paleo-depositional model for the two wells were thus established.

Results & Conclusion

Manual dip picking from the high-resolution micro-resistivity image helped in generating high resolution geological surfaces. The regional structural model was thus updated using these high resolution surfaces. The 3D structural model illustrated the presence of a monoclinal structure between Well-A and Well-B with the paleo-slope towards SE (Fig. 4 & 5). The analysis from the cross bedding dip data of both the wells suggested a bi-modal paleo-current trend towards S-SE and S-SW, with prominent direction trends towards SE. The basin was tilted southwards during Oligocene to Pliocene which resulted in SE dipping monoclinal structure and subsequently lead to the SE depositional direction in these wells.

The high resolution image analysis resulted in defining the sedimentary structures which were used to delineate the various facies associations. The different facies associations served as indicatives of a probable depositional environment. The sedimentary facies were found to change from delta front to delta plain setting. The 3D facies model helped in further updating the formation tops with a high degree of confidence and outlining the extension and dispersion of the sand bodies. The cross-section of the 3D facies model along Well A and Well B show the undulating nature of the sand body between the two wells. It also shows the dispersion of shaly sandstone and carbonatic sandstone within the sand body.

The 3D facies model generated after structural restoration and sedimentological re-computation resolves the sedimentological complexities between Well A and Well B (Fig. 6 & 7). The model can further be used for optimizing the horizontal well trajectories to ensure the well remains within the reservoir.

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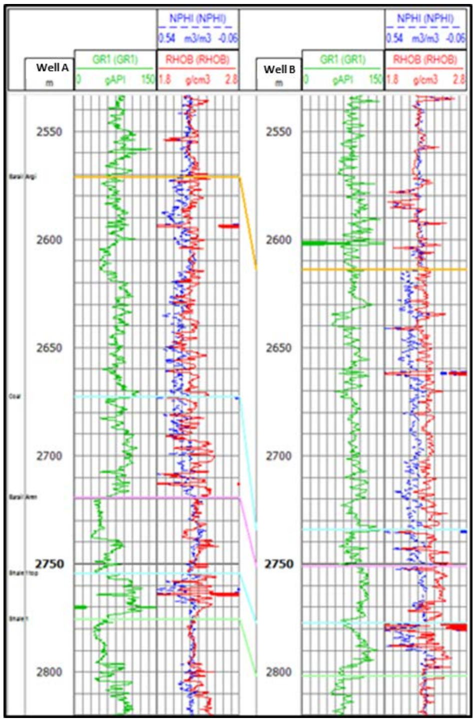

Figure 2: Stratigraphic correlation between Well A and Well B.

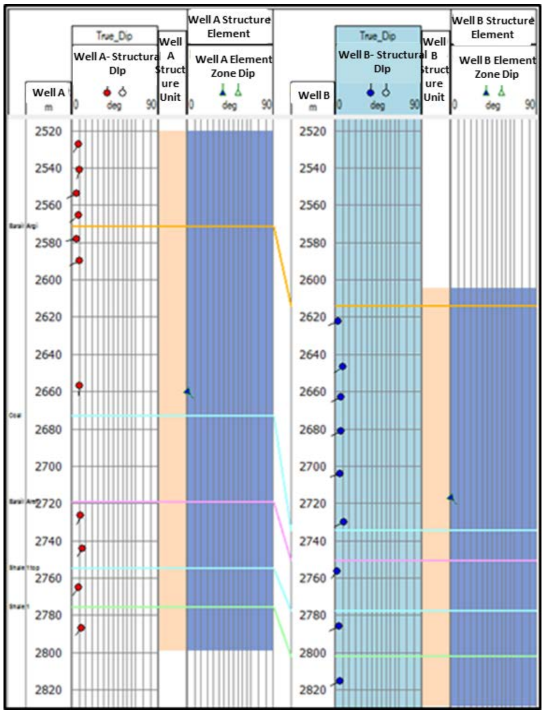

Figure 3: Local Structural Dip and structural zonation for Well A and Well B.

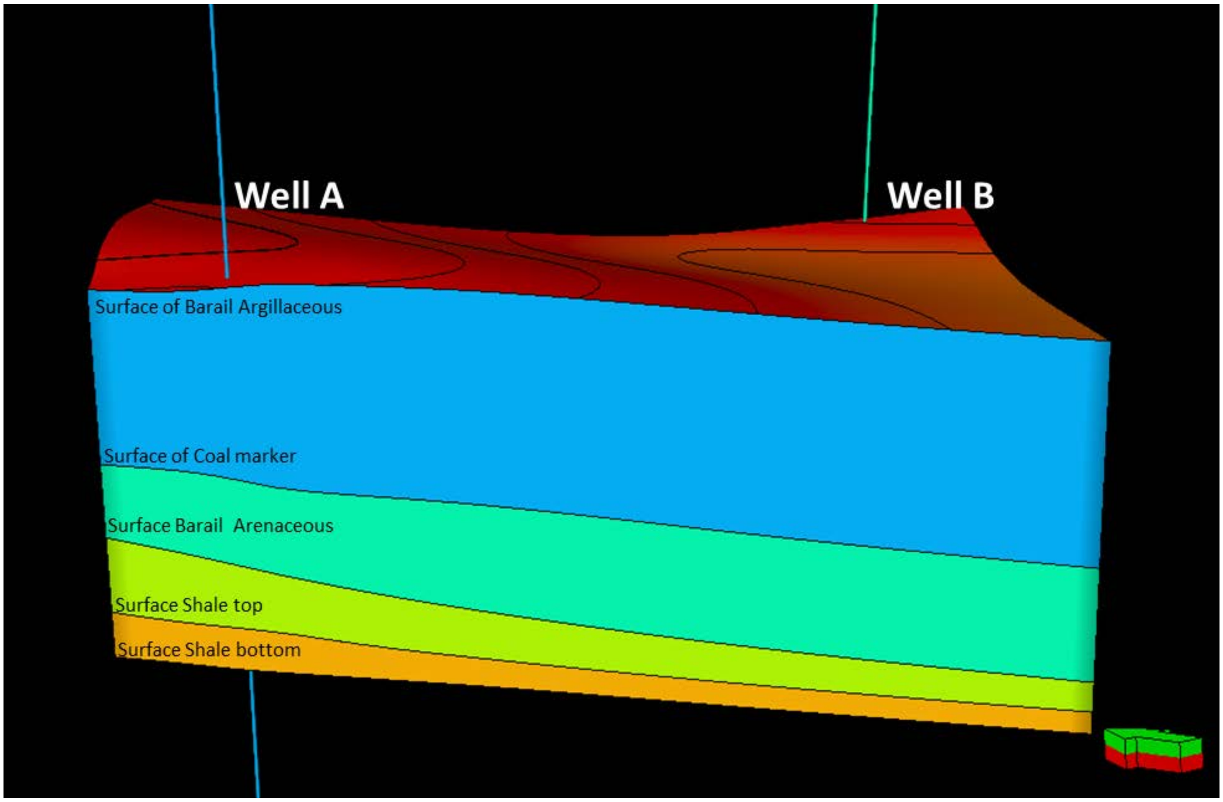

Figure 4: Monoclinal 3D structural model between Well A and Well B.

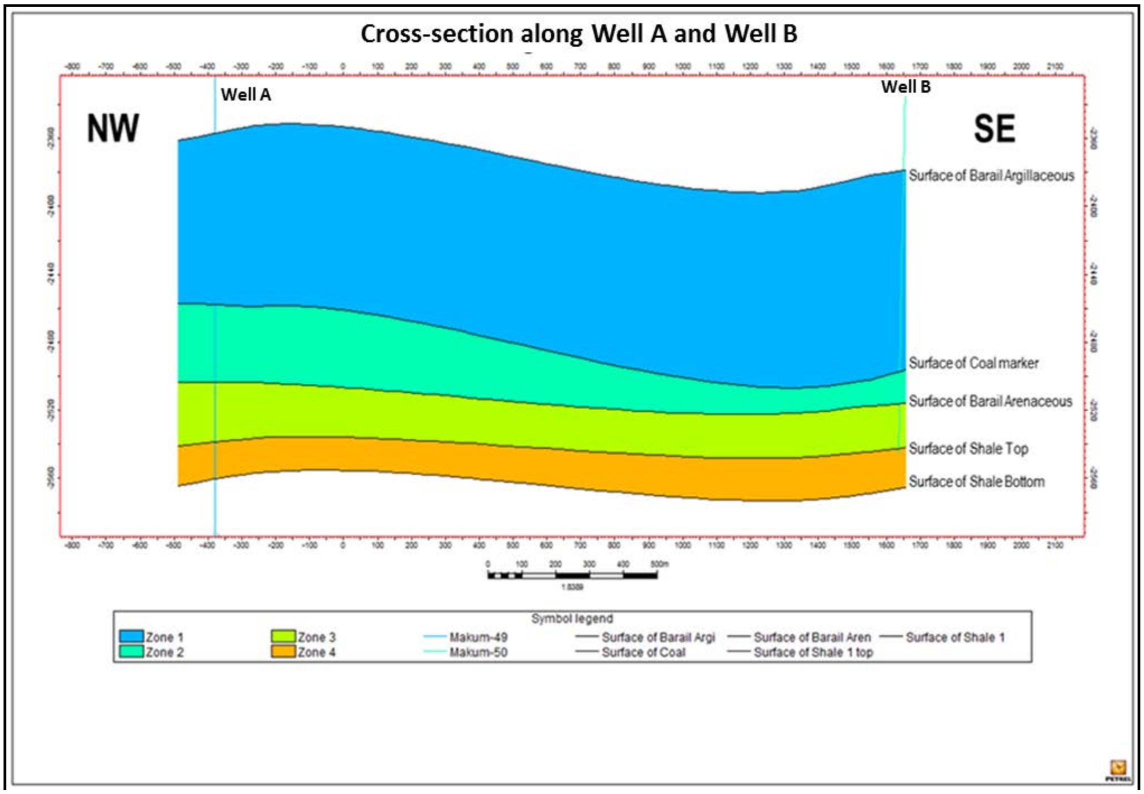

Figure 5: Cross-section of the structural model along Well A and Well B.

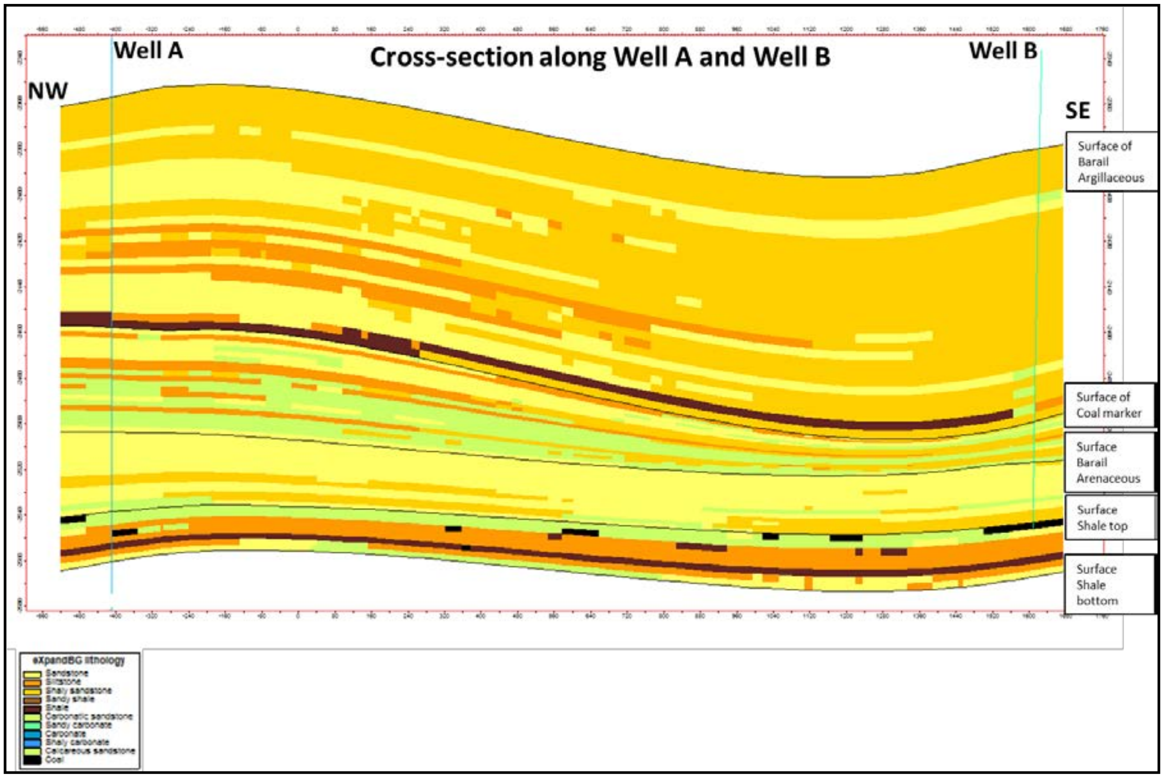

Figure 6: Cross-section of 3D facies model along Well A and Well B.

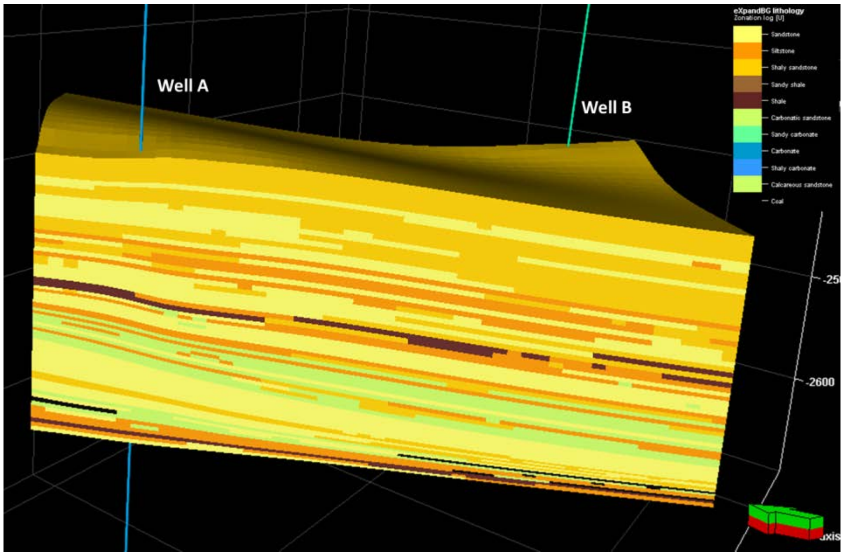

Figure 7: 3D high resolution facies model for Well A and Well B.

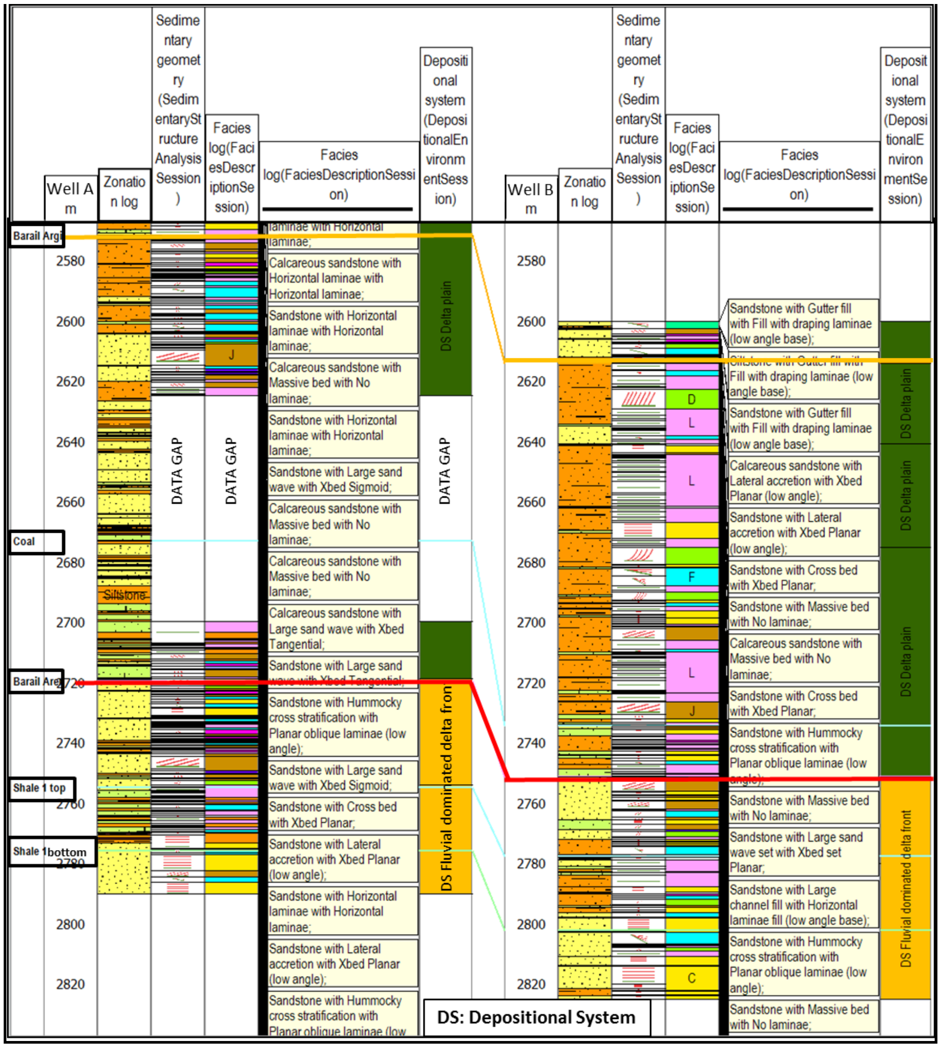

Figure 8: Facies analysis and depositional environment determination for Well A and Well B