RESERVOIR CHARACTERIZATION AND LITHOFACIES CLASSIFICATION WITHIN BARAIL ARENACEOUS UNIT OF DELTAIC SETTING USING WELL LOG AND CORE ANALYSIS IN MAKUM-NORTH HAPJAN OIL FIELD, UPPER ASSAM BASIN, INDIA

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Abstract

The Makum-North Hapjan oil field is located in the Upper Assam shelf on the southern bank of the river Brahmaputra. One of the major producing reservoirs is the Barail Arenaceous unit of Mid Eocene-Early Oligocene age. The Barail Arenaceous unit exihibits complex vertical and lateral variations in lithofacies. An integrated approach of the Gamma ray log motifs, stratigraphic well correlation technique, Image logs, and available cores has been adopted to establish geometry, orientation, spatial distribution and environment of deposition. From the analytical study, the upper part of the Barail Arenaceous unit (Barail Fourth Sand) exhibit characteristics of the distributary channel deposits in the delta plain settings, with fluvial channels, periodic stage fluctuations, switching and avulsion of channels and accumulation of fines in the adjacent low-lying areas.

The lithofacies distribution of upper part of Barail Arenaceous unit can be subdivided into three sub units viz. Lower, Middle and Upper in ascending order of succession. The lower subunit is an active distributary channel fill deposits characterised by thick bedded clean sandstone exihibiting cylindrical or blocky GR log curve with abrupt lower / transitional base and comprises of trough cross bedded and minor ripple laminated, medium to fine grained sandstone with SSE & SSW dip directions. The overlying “Middle” lithofacies which is relatively thin sand body of blocky log profile comprising fine to medium grained sandstone, moderate to poorly sorted in nature with current bedding as well as ripple drift laminations showing S-SW and S-SE dip distribution. This lithofacies representing a transition zone. The “Upper” lithofacies representing the upper part of the distributary channel deposits showing fluvially influenced fine grained progression of grain size and sedimentary structures of which dip is dominantly towards the SW direction. This sequence might be attributable to the deposits of crevasse splays, levees or fills of floodplain-drainage channels with silty sands and silty clays.

The reservoir property maps of net sand thickness (22-70 m) map, high net-to-gross ratio(0.90 -1.00) maps, average porosity maps (4.0-26%), stratigraphic well correlation reveal the reservoir characterizations of the lithofacies both vertically and laterally and will guide in future field development plan as well as to the placement of horizontal wells in the best part of the reservoir.

Introduction

The Makum-North Hapjan oil field is one of the most prolific oil producers in the Upper Assam Basin, located on the southern bank of the Brahmaputra River. The field is a faulted anticline of about 35 sq. km in size at the Barail Arenaceous level, with the major axis of the structure trending in NE-SW direction. A collinear series of normal faults divides the structure into the Makum and North Hapjan structural compartments. (refer Figure-1). The lithofacies analysis of the upper part of the Barail Arenaceous Unit (Barail Fourth Sand) from the integrated approach of log motifs, stratigraphic well correlation technique, Image logs and available core analysis exhibits a complex vertical and lateral variations in lithofacies. The Barail Arenaceous unit is predominantly of clastics, comprised of sandstones, siltstones and mudstones with locally deposited coals.

Results and Discussions

The study of the sand layer maps of the upper part of the Barail Arenaceous Unit (refer Figure-2) shows the long and narrow strip of sand body plan, slightly curved broadband like thickness, laterally connected and also the shape of a surface like distribution, reflecting the style of distributary channel fill deposits in the deltaic environment. The sand bodies of a delta with high lateral variability is built by the coalescence of multiple distributary channels and few mouth bars. These deposits in the delta plain settings are characterized by the fluvial channels, periodic stage fluctuations, switching and avulsion of channels and accumulation of fine materials in the adjacent low-lying area.

Based on the analysis of the wireline log data, available core data and well-to-well stratigraphic correlations, the distributary channel fill deposits of the Barail Fourth Sand is divided into three lithofacies viz. A (lower), B (middle) and C (upper) in ascending order of succession (refer Figure-3) defining the thickness distribution of the sand depositional units and gamma ray log characteristics.

The lower lithofacies “A” is characterized by thick bedded sandstone (*clean sand zone*) with inter bedded sandstone and friable silty shale laminae representing the deposition in the lower reach of distributary channels with SSE & SSW dip directions (refer Figure-4). The GR log curve frequently appear as cylindrical or blocky with abrupt lower / transitional base. Some of the successions show erosive base sand with basal lags, fining and thinning upward, trough cross-bedded sands, and minor ripple–laminated finer sands. The smooth cylindrical curve is commonly indicative of more uniform massive bedding and consistent depositional energy within the bed. The interbedded shale laminae represent the deposition of superimposed (amalgamated) channel belts. The lithofacies with a maximum thickness (up to ~ 46 m) is observed towards the Eastern part and Central part which gradually decreases towards the South-Western (SW) part of the structure.

The overlying middle lithofacies “B” which is a thin sand body (max ~21 m) of deposition in the channel belts representing *a transition zone*. The GR log profile showing the blocky curve with abrupt lower boundary/ transitional base. The erosional bases of some of the sandstone beds may be attributable to erosion of the substrate by the high-energy flows in the fluvial flood stage. This facies is characterized by fine to medium grained sandstone, moderate to poorly sorted in nature with current bedding as well as ripple drift laminations showing S-SW and S-SE dip distribution (refer Figure-4). This lithofacies is not present in all the wells of the area and its maximum trend is along the axis of the structure in NE-SW direction and the gradual decrease in thickness is towards the North-Western direction which attains a minimum thickness and found absent in some of the wells.

The uppermost distributary channel fill deposits of lithofacies “C”, which is a thin sand body of “bell shaped” curve representing fining upward sequence of which dip is dominantly towards the SW direction (refer Figure-4). This sequence indicating the decreasing depositional energy towards the top of the unit. In some of the wells, the abrupt base of the bell shaped unit is commonly indicative of an erosion or scour surface. This sequence might be attributable to the deposits of crevasse splays, levees or fills of floodplain-drainage channels with silty sands and silty clays of fluvial deposits. Decrease in activity of the channels, lateral migration of the channel or more commonly from channel abandonment resulted in fining and thinning upward sequence. The maximum thickness is observed in the Eastern part (up to ~ 46 m) and central part of the structure. The net thickness is gradually decreasing towards the South-Western (SW) part and attains a minimum thickness (up to ~ 4 m) further in the direction.

The average effective porosity distribution of the three lithofacies is revealing the reservoir characterization in both vertically and laterally, of which “A” (12-25%) & “B” (10-26%) having good porosities compared to the upper lithofacies “C” (4.0-25%). The porosity distribution of lithofacies “C” is showing minimum (4%) in the north-eastern part and southern part (about 7%), whereas the maximum trend is towards western, central and northern part. The overall porosity distribution trend in both the lithofacies “A” & “B” showing similar pattern. The lithofacies “B” exhibiting higher porosity in the western, northern and south-eastern part. The porosity is relatively less towards the extreme SW-SSW part of the structure in both the lithofacies “A” & “B”.

Conclusions

The present study demonstrates the upper part of the Barail Arenaceous unit with complex vertical and lateral variations of lithofacies and the idealized log motifs showing the deltaic distributary-channel fill deposits. The distributary channel deposits in the delta plain settings are characterized by the fluvial channels, periodic stage fluctuations, switching and avulsion of channels and accumulation of fine materials in the adjacent low-lying area. These lithofacies show erosively base sand with basal lags that fine upwards, trough cross-bedded sands, ripple–laminated fine to medium grained sands, topped by the muds indicative of emergence.

The reservoir property maps of net sand thickness (22-70 m) map, high net-to-gross ratio(0.90-1.00) maps, average porosity maps (4.0-26%), stratigraphic well correlation reveal the reservoir characterizations of the lithofacies both vertically and laterally and will guide in future field development plan as well as to the placement of horizontal wells in the best part of the reservoir.

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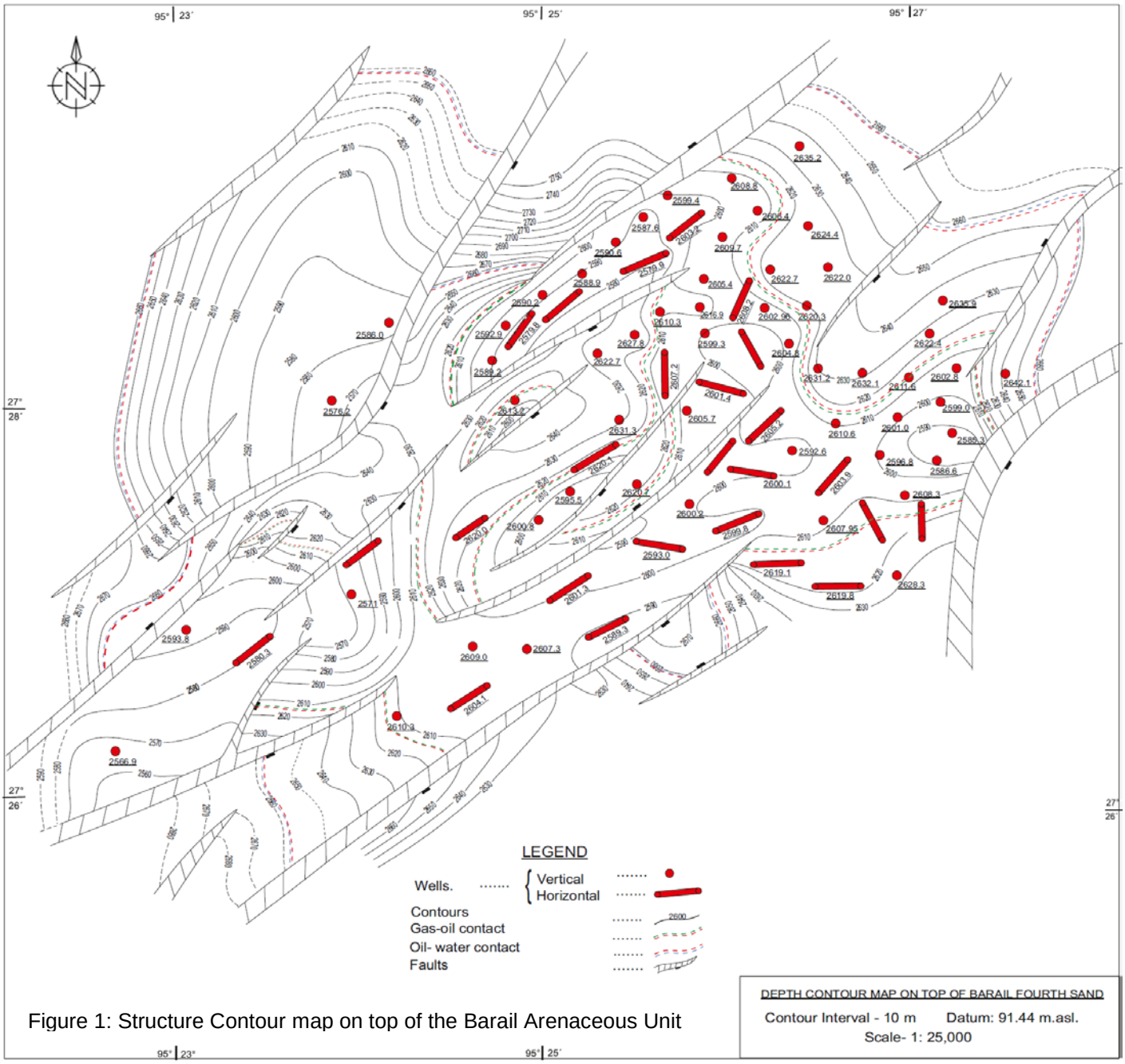

Figure 1: Structure Contour map on top of the Barail Arenaceous Unit

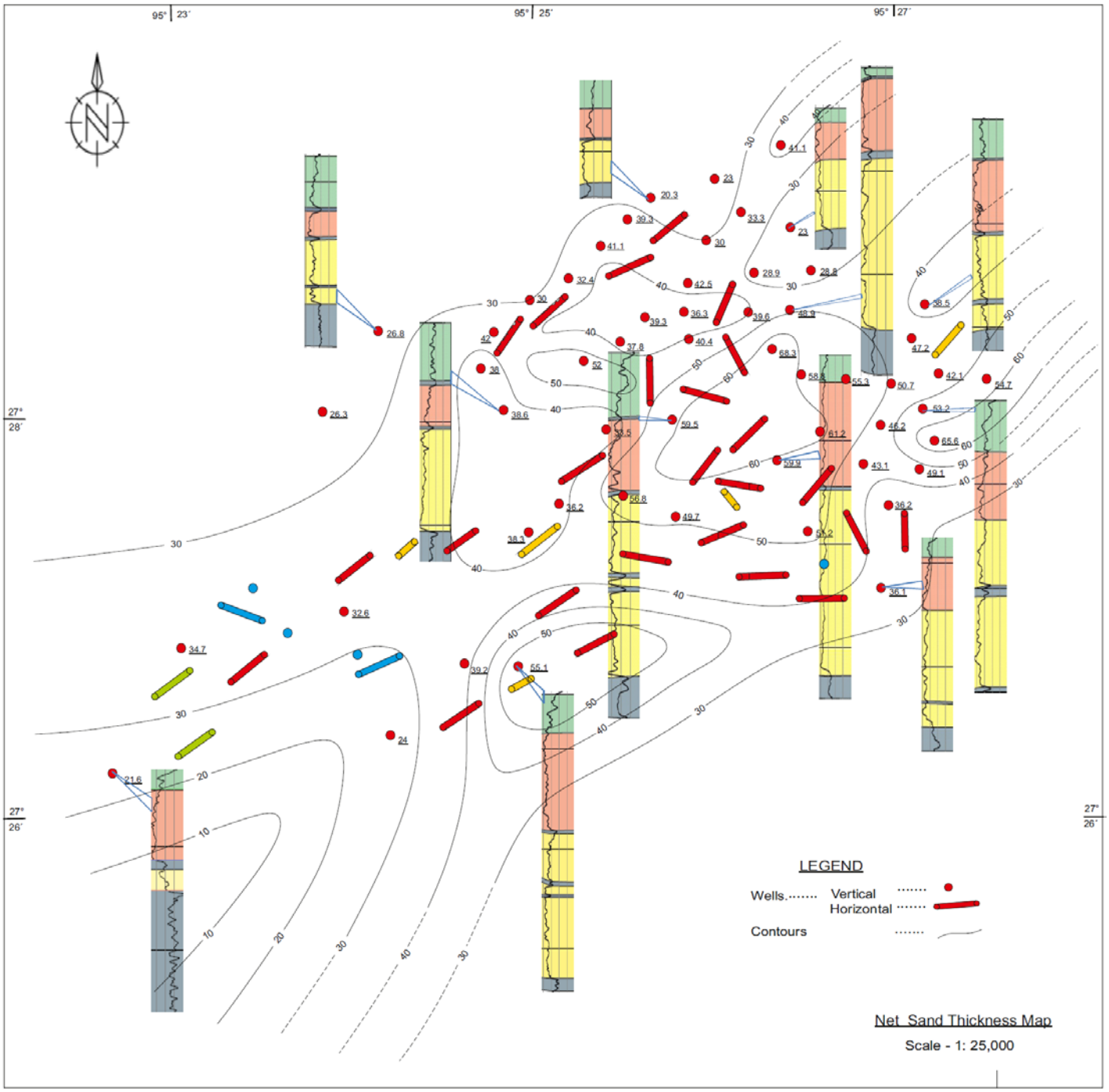

Figure 2: Net Sand Thickness map of the Barail Arenaceous Unit

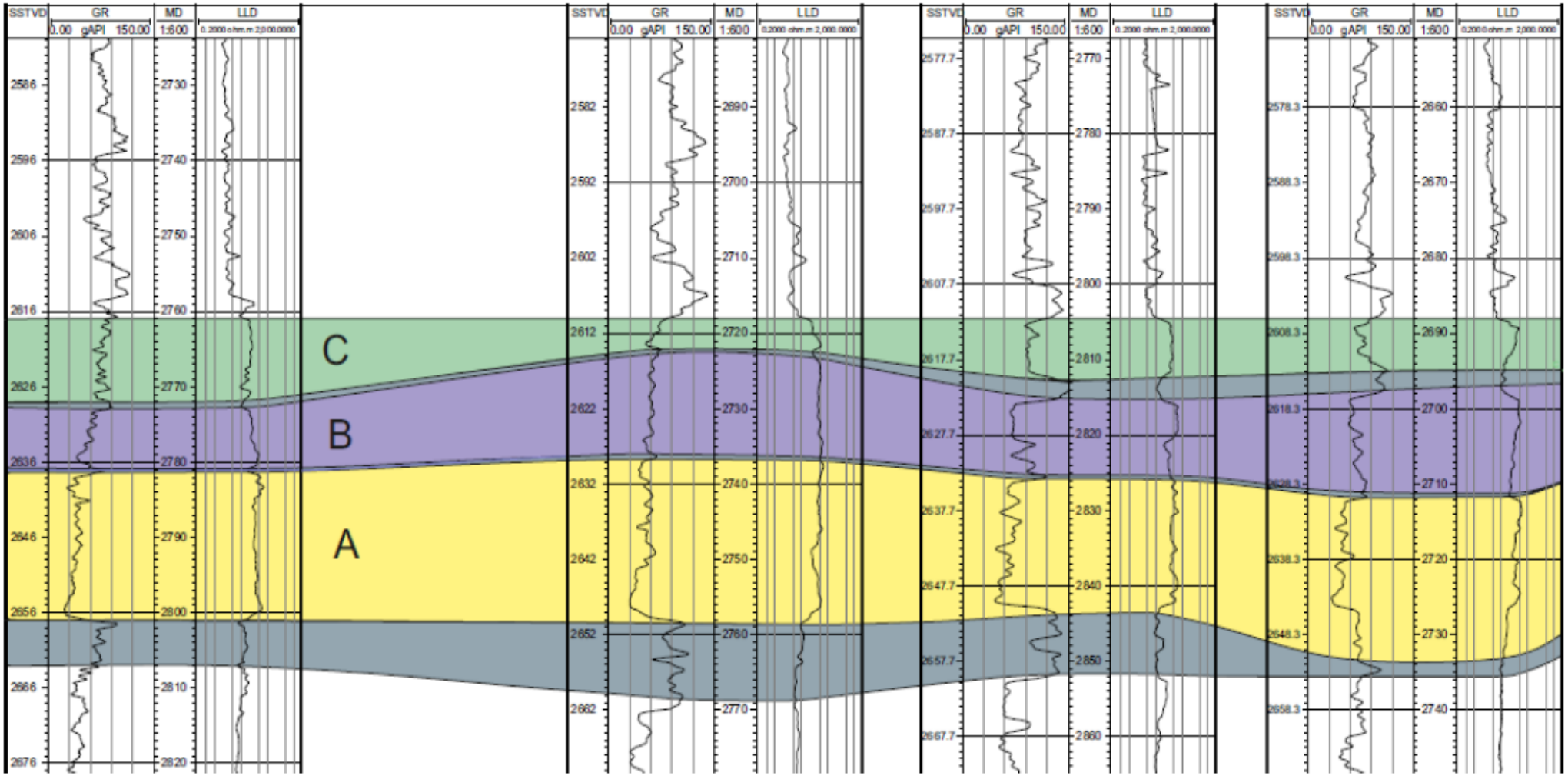

Figure 3: Stratigraphic Well Correlation showing the three lithofacies of the Barail Arenaceous Unit

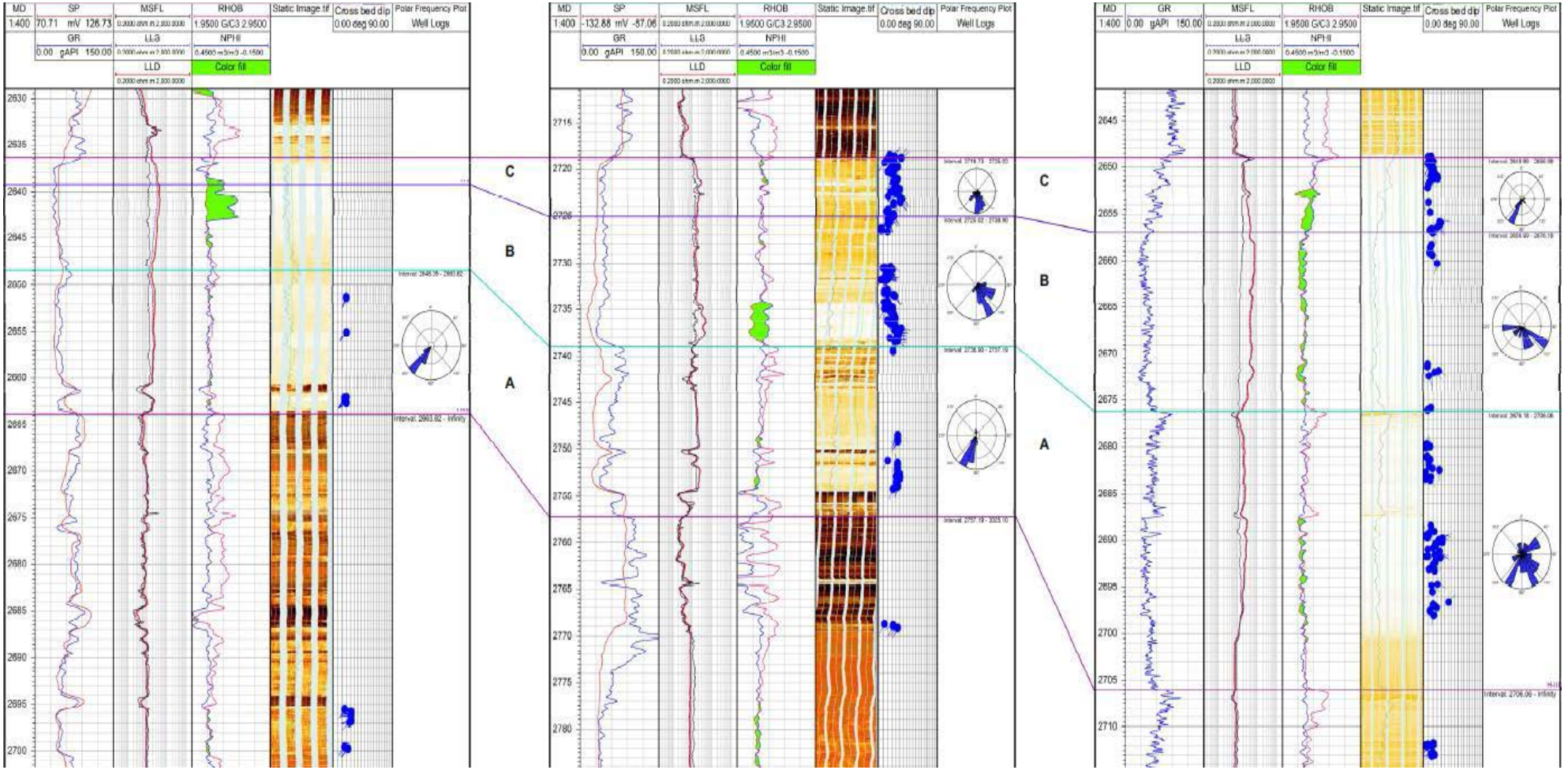

Figure 4: Palaeoflow direction analysis from FMI logs